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AN ANALYSIS OF A SEVERE LOCAL STORM
USING ISENTROPIC TRAJECTORIES

by

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ABSTRACT:

One and one-half hour isentropic trajectories obtained from an objective computer technique for the 308K, 312K, 320K and 332K isentropic surfaces are investigated for the May 28, 1967, severe local storm case in the National Severe Storm Laboratory (NSSL) network. In conjunction with the trajectories, air parcel properties of vertical motion, acceleration, divergence, vorticity, static stability and total energy have been studied with respect to development, growth, movement and decay of the storm system. Basic assumptions are that the flow is frictionless and adiabatic over the entire grid. The results show that the observed winds do provide some skill in formulating isentropic trajectories which demonstrate the presence of storm activity in the specific region. The investigation of a mesoscale inertial-gravity wave having a wave length of 150 KM, period of 3 hours and phase speed of 14 m sec^{-1} is also presented, with its possible correlation to the onset of the severe storm.

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This report covers one aspect of the research conducted under contract to the Naval Weapons Center, China Lake, California. It is, with a few exceptions, as authored by Lieutenant Kenneth L. Van Sickle, USN. While this report is a final report, it does not indicate that studies have been completed. Other investigations are currently in progress and will be reported as warranted.

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Kenneth Lee Van Sickle
Lieutenant, United States Navy

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One and one-half hour isentropic trajectories obtained from an objective computer technique for the 308K, 312K, 320K and 332K isentropic surfaces are investigated for the May 28, 1967 severe local storm case in the National Severe Storms Laboratory (NSSL) network. In conjunction with the trajectories, air parcel properties of vertical motion, acceleration, divergence, vorticity, static stability and total energy have been studied with respect to development, growth, movement and decay of the storm system. Basic assumptions are that the flow is frictionless and adiabatic over the entire grid. The results show that the observed winds do provide some skill in formulating isentropic trajectories which demonstrate the presence of storm activity in the specific region. The investigation of a mesoscale inertial-gravity wave having a wave length of 150 KM, period of 3 hours and phase speed of 14 m sec^{-1} is also presented, with its possible correlation to the onset of the severe storm.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

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1. INTRODUCTION

The severe local storm is an extremely complex meteorological phenomenon which can lend itself to interesting and challenging research. The approaches one can take for extensive studies are almost unlimited as evidenced by the wealth of literature on various aspects of the severe storm. Yet there are many questions on the formation, movement, growth and decay of these systems which remain unanswered. Similar synoptic conditions may seem to exist during two separate time periods, and yet storms may be forecasted to develop and then not form, or vice-versa. In particular, the extent to which an individual storm may evolve is not reasonably understood or predictable.

A. SEVERE STORM RESEARCH

In 1947 a comprehensive study was undertaken in the Thunderstorm Project which was perhaps the beginning of extensive scientific efforts into the study of severe local storms. From this project Byers and Braham (1949) provided new concepts on the structural features of such storms. The National Severe Storms Project, initiated in 1961, was an effort designed to study Great Plains convective storms and the environment in which they form. More recently the Barbadoes Experiment, which has provided data for study of tropical cumulus convection, and Project Storm Fury, for the study of hurricanes, have enabled investigators to carry on detailed research into severe storm characteristics.

Mesoscale networks located in various regions, with instrumentation positioned at specified spacing, have provided for collection

of data for certain research objectives. In particular, the National Severe Storms Laboratory (NSSL), Norman, Oklahoma, has a systematic network of surface and upper air reporting stations and radar facilities.

There have been several studies involving kinematic properties which have given insights into storm characteristics. Williams (1962) investigated small-scale kinematic properties of surface horizontal velocity divergence, horizontal stretching deformation, and the vertical component of horizontal shearing deformation for isolated thunderstorms. He found the intensity and rate of change of these properties for small scale systems were 2 to 3 orders of magnitude greater than those normally measured on the gross synoptic scale. Endlich and Mancuso (1968) investigated a number of kinematic quantities using objective analysis procedures and compared them with storm developments. They found vorticity production in low levels and horizontal divergence in the upper troposphere to be good objective indicators of severe storm activity. Fankhauser (1964) used a statistical and observational approach to propose that the translation of convective complexes is related in a systematic way to the mean wind through the tropospheric layer in which the clouds are imbedded, and that this relationship is dependent on the unique character of the mean wind field. Hammond (1967) investigated an isolated airmass storm, which moved rapidly northeastward across central Oklahoma where its movement was to the left of all winds in the middle and upper troposphere. He concluded that the same environmental wind field can account for the characteristic organization and structure of either right or left moving storms,

depending on storm velocity. Studies by Browning and Fujita (1965), Newton and Fankhauser (1964) and Browning and Ludlum (1962) have shown that large thunderstorms normally travel to the right of the winds in the lower and middle level of the troposphere. Matsumoto, Ninomiya and Akiyama (1967) studied the relations of cumulus convections and the mesoscale convergence field over the coastal area of Japan and found that well developed cumuli exist only in the area of surface convergence of more than 10^{-4} sec^{-1}.

B. ISENTROPIC ANALYSIS AND TRAJECTORY STUDIES

The use of isentropic analysis to study the physical processes at work in the atmosphere is well known since Rossby (1937) introduced the technique. The analysis and its uses are well described by Namias (1940). Tongues of dry and moist air from specific humidity analysis on isentropic surfaces show moisture sources and instability regions for thunderstorm activity.

Calculations of isentropic trajectories for the study of moisture sources, vertical motions, velocity accelerations, type of air and circulations within systems, vorticity sources, and for investigations of transports of pollutants and trace substances has long been appealing since non-precipitating motions in the free atmosphere may be assumed to be isentropic for limited periods of time. Many investigators have used graphical calculations from isotach and streamline analysis to determine the trajectories (Danielsen, 1959; Reiter and Danielsen, 1960; Reiter, 1963). The use of isentropic trajectories in thunderstorm studies (Bradley and Feteris, 1966; Feteris and Stout, 1966; Carlson and Ludlum, 1968) can provide useful information in the study of these mesoscale systems.

It is intended in this research to investigate, by the use of isentropic trajectories, meteorological properties of air parcels and their relationship to severe local storms. Several questions will be considered:

1. Do isentropic trajectories over a short period of time describe flow patterns which adequately show the formation, growth, movement, and decay of the severe storm?

2. Do associated parameters computed along isentropic trajectories describe motions directly related to the dynamics of the severe storm?

3. Does a combination of any computed parameters correlate well with the storm?

4. Is there an oscillation or wave phenomenon, in particular a gravity-inertial wave, that can be detected from the data and/or computed parameters which might relate to the local severe storm?

It is intended to deal with these specific questions in the ensuing sections by conducting a case study of a specific severe storm system. The isentropic trajectories will be computed from an objective computer technique in order that a sufficient number of trajectories and isentropic surfaces can be studied for the severe storm case.

2. OBJECTIVE ISENTROPIC TRAJECTORY COMPUTER MODEL

Danielsen (1961) introduced an objective method for computing isentropic trajectories based on the total energy equation. This provided the foundation for the technique for which Mahlman (1968) developed a computer method for an objective computation of adiabatic three-dimensional trajectories.

A. BASIC DESIGN

Utilizing the graphical method by Danielsen (1961), the computer program applies an objective method which confines the computed trajectory from deviating too far laterally from its true position. The concept of the system eminates from the horizontal equation of motion in isentropic coordinates, which is

$$\frac{d\mathbf{V}}{dt} = -f\mathbf{k} \times \mathbf{V} - \nabla_\theta M + \mathbf{F} \qquad (1)$$

where $\mathbf{V}$ is the two dimensional horizontal wind vector, f the Coriolis parameter, $\mathbf{k}$ the unit vector in the vertical, ∇_θ the two dimensional gradient operator on a surface of constant potential temperature θ, M the Montgomery stream function, and $\mathbf{F}$ the friction force.

The basic model utilizes variables of true wind direction, wind speed, pressure and Montgomery stream function at each point in a four-dimensional (x, y, θ, t) grid. The first step in the program is to obtain u and v components of the velocity field, with the effects of latitude/longitude type griding included in the calculations over the data area. Then, the u and v fields are linearly interpolated to give values at twelve time step intervals.

The first approximation of the trajectory is using a straightforward kinematic approach. Beginning at a grid point, a parcel is displaced for one time step using the initial values of u and v to determine the length and direction of the displacement. This displacement is determined by:

$$S = \overline{V}\Delta t \qquad (2)$$

where S is the displacement and $\overline{V}$ is the average wind velocity along the trajectory over a Δt interval. Then the time interpolated u and v values are spatially interpolated from the four nearest grid points to the parcel to obtain new u and v wind components at the parcel's new position. These new values are then used to extrapolate the parcel for the next time step. This process is repeated until twleve time steps are reached. At each point along the trajectory a test is made to determine if the trajectory remains within the original grid. If not, then the trajectory is terminated at the point where it leaves the field and a new trajectory is begun at the next grid point. These isentropic kinematic trajectories can provide a valid result as long as the original wind fields have been adequately specified, and the time interpolations are satisfactory.

It is important to note that for inclusion of changes in the Montgomery stream function, Mahlman (1968) indicated that the corrections were sensitive to analysis errors in the M field, rapid changes of wind direction perpendicular to the estimated trajectory path, and for cases where the wind speed is less than 10 m sec^{-1}. Since preliminary studies of the data indicated cases where the wind flow was perpendicular to isolines of Montgomery stream function and wind speeds less than 10 m sec^{-1}, the subsequent research was thus

conducted from the isentropic kinematic trajectories. The incorporation of adjustments for changes in Montgomery stream function is a separate subroutine in the program so, if only kinematic trajectories are desired, the subroutine can be left out. The programming is included in Appendix B.

B. MODIFICATIONS FOR SEVERE STORM RESEARCH

An additional field of relative humidity was added in order to include a moisture constituent. Routines to compute certain meteorological parameters were incorporated so that initial conditions and variations along the kinematic isentropic trajectories could be studied. These routines include calculations of:

$$\zeta_\theta = \left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right)_\theta + f \tag{3}$$

$$D_\theta = \left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right)_\theta \tag{4}$$

$$A_\theta = \left(\frac{\partial u}{\partial x} - \frac{\partial v}{\partial y}\right)_\theta \tag{5}$$

$$B_\theta = \left(\frac{\partial v}{\partial x} + \frac{\partial u}{\partial y}\right)_\theta \tag{6}$$

$$\sigma = -\frac{\partial \theta}{\partial p} \tag{7}$$

where ζ_θ is the absolute vorticity, D_θ the horizontal divergence, A_θ the stretching deformation, B_θ the shearing deformation, and σ the static stability. Also the height (z), specific humidity (q), saturated specific humidity (q_s) and temperature (T) fields for each isentropic surface and data time were determined. Along each kinematic trajectory the initial and final values of specific humidity, saturated specific humidity, divergence, absolute vorticity, Montgomery stream function, kinetic energy, total energy, static stability, and

potential vorticity were computed. Total energy, in units of 10^7 ergs gm^{-1}, was defined as:

$$TE = C_p T + gZ + Lq + \frac{V^2}{2} \tag{8}$$

where C_p is the specific heat at constant pressure and L the latent heat. Potential vorticity was computed as:

$$P = \sigma \zeta_\theta \tag{9}$$

where P is in units of $10^{-10} {}^oK$ sec cm gm^{-1}.

The latitude and longitude positions, u and v components, and interpolated height at each of the twelve time steps of the trajectory were obtained. The average vertical motion ($\bar{\omega}$) along the trajectory was calculated using the procedure:

$$\bar{\omega} = \frac{P_f - P_i}{\Delta t} \tag{10}$$

with $\bar{\omega}$ in mb hr^{-1} and where the i and f refer to initial and final pressure over the interval Δt. The acceleration of the parcel over the trajectory was also calculated. Finally, the pressure at which the air parcel would become saturated (P_s) and the time of saturation (t_s) were determined by:

$$P_s = P_i \left[1.0 + \left(\frac{q_i - q_{si}}{q_{si}} \right) \left(\frac{L}{C_p T} - 1 \right) \right]^{-1} \tag{11}$$

$$t_s = \frac{P_s - P_i}{P_f - P_i} \Delta t \tag{12}$$

where the i and f refer to initial and final points on the trajectory and P, q and q_s are as previously defined.

A routine to utilize the CALCOMP plotter with the IBM OS/360 computer was included in order to graphically display the computed trajectories on a x, y grid system. The data generated by the program was displayed such that subsequent studies could be made.

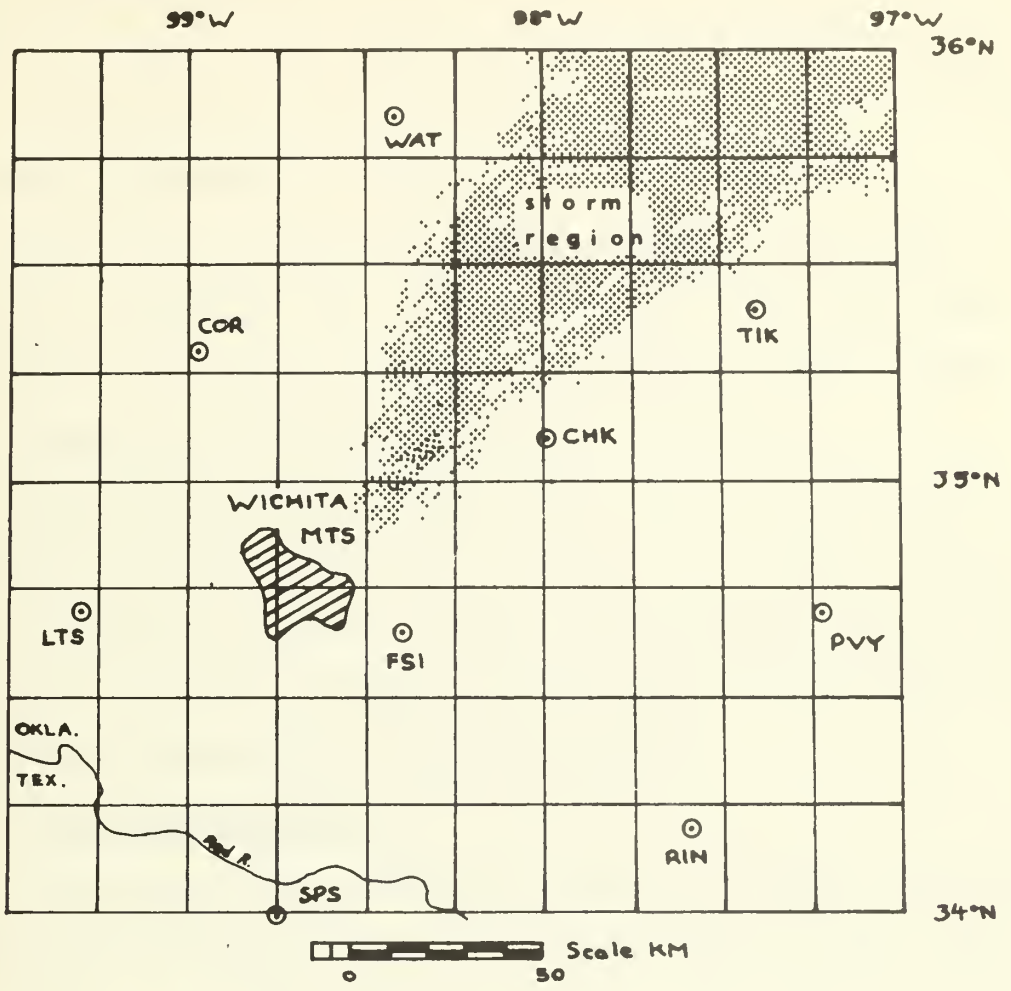
3. DATA AND STORM CHARACTERISTICS

Data that was considered in the case study are from observations in the NSSL mesoscale network on May 28, 1967. Upper air data from nine radiosonde stations systematically spaced over the network region (Fig. 1) provided data at 1700, 1830, 2000, 2130 and 2300 GMT.

Utilizing computer processing of mesoscale rawinsonde data (Kreitzberg and Brockman, 1961), fields of Montgomery stream function (10^7 erg gm^{-1}), wind direction (deg from north), wind speed (m sec^{-1}), pressure (mb) and relative humidity (%) from the isentropic plane section were hand analyzed over the network area. Allowances for balloon drift and non-simultaneous releases were not taken into account. However, a comparison was made between the original analysis and a re-analysis taking into account balloon drift and storm location. These results are reported on in later sections. A 9 x 11 latitude-longitude grid (Fig. 1), with grid separation of .25 degrees, was established (southeastern boundary -34N, 97W). Analyzed data were then interpolated to the nearest grid point. Theta surfaces 308K, 312K, 320K and 332K were those selected for the analysis levels. The 308K theta surface was the lowest level for which data were available at most stations over the time periods. The 332K theta surface was selected as being representative of the upper level of storm influence. This surface was located at a height of about 300 mb.

A. BRIEF SYNOPTIC ANALYSIS

The surface synoptic situation over Oklahoma at 1800 GMT on May 28, 1967 indicated a weak high pressure (1018 mb) over the Oklahoma Panhaldle, with low pressure areas located over NW Missouri



CHK - Chickasha, Oklahoma
COR - Cordell, Oklahoma
FSI - Ft, Sill, Oklahoma
LTS - Altus, Oklahoma
PVY - Pauls Valley, Oklahoma
RIN - Ringling, Oklahoma
SPS - Sheppard AFB, Texas
TIK - Tinker AFB, Oklahoma
WAT - Watonga, Oklahoma

Figure 1, NSSL upper air network and latitude-longtitude grid system, Stippled area represents storm region,

(1010 mb) and in central New Mexico (1005 mb). A weak cold front lay between the two low areas, passing through central Oklahoma. The front remained nearly stationary during the period under consideration, but began to dissipate and become a warm front by 2400 GMT.

The 1800 and 2400 GMT 500 mb height synoptic analyses showed straight southwesterly flow of about 15 kt. The 300 mb height chart indicated westerly flow of 20-30 kt at 1200 GMT with winds shifting to southwesterly and increasing slightly by 2400 GMT.

As reported by Fankhauser (1968), the characteristics were only marginally conducive to thunderstorm formation, with slightly negative stability indexes on morning soundings. The stationary front provided sufficient low-level convergence to set off weak convective storms over the northwest portion of the network by midday.

B. STORM CHARACTERISTICS

The initial radar presentation available for study was at 1817 GMT. Small echoes were present in the western grid area about 30-50 nautical miles from station TIK at this time. Larger and more intense echoes were present by 2000 GMT. Storm tops to the northwest of station TIK exceeded 11 KM in height, and the storm system was oriented SW-NE across the grid area. The 2100 GMT radar reflection indicated the system to the west of station TIK had decreased in intensity and size, with tops reaching to about 9 KM.

Storm motions used for calculating the relative trajectories were obtained from viewing surface radar presentations of similar echoes. These velocities were determined as:

TIME DIFFERENTIAL	COURSE (deg from)	SPEED (m sec^{-1})
1700-1830 GMT	---	0.0 (no echo)
1830-2000	268	1.5
2000-2130	274	2.1
2130-2300	272	4.1

Fankhauser (1968) indicated that echo velocity was 247 (deg from) at a speed of 8 m sec^{-1}. Also this course and speed were remarkably constant throughout the lifetime of the storm. The mean wind direction through the atmospheric layer for the 1700-2300 GMT period was 247 (deg from) and had a mean wind speed of 8 m sec^{-1}.

4. DISCUSSION OF RESULTS

A. SEVERE STORM RELATIONSHIPS TO BASIC DATA ANALYSES

There were five basic fields which were analyzed on the isentropic surfaces in the mesoscale network. No objective smoothing was performed on these fields. Part of the research was to investigate these basic fields and to determine if they provide an indication of storm development, growth, movement and decay.

The mesoscale analysis over the NSSL network disclosed that a region of lower Montgomery stream function values was maintained near the middle of the grid area and to the southwest of the storm region. This prevailing pattern was consistent on each theta surface. Values were generally larger at the initial data time of 1700 GMT and then decreased in value over the entire grid as time progressed. However, the predominant contour pattern remained the same (values on the 308K theta surface at 1700 GMT ranged from 310.40 joules gm^{-1} to 310.62; at 2130 GMT values ranged from 310.17 to 310.45). The horizontal gradient ($\nabla_\theta M$) was stronger to the SE of the storm area. A stronger gradient existed at 2300 GMT on the theta surfaces than for previous times. It was noted that the thunderstorm had almost dissipated by this time. A dome of colder temperatures was associated with the low stream function values. This low M value and strong gradient region could be associated with the stationary front which existed over central Oklahoma and would indicate the thunderstorm was occurring northwest of the front. Figure 2a is an example of the Montgomery stream function pattern.

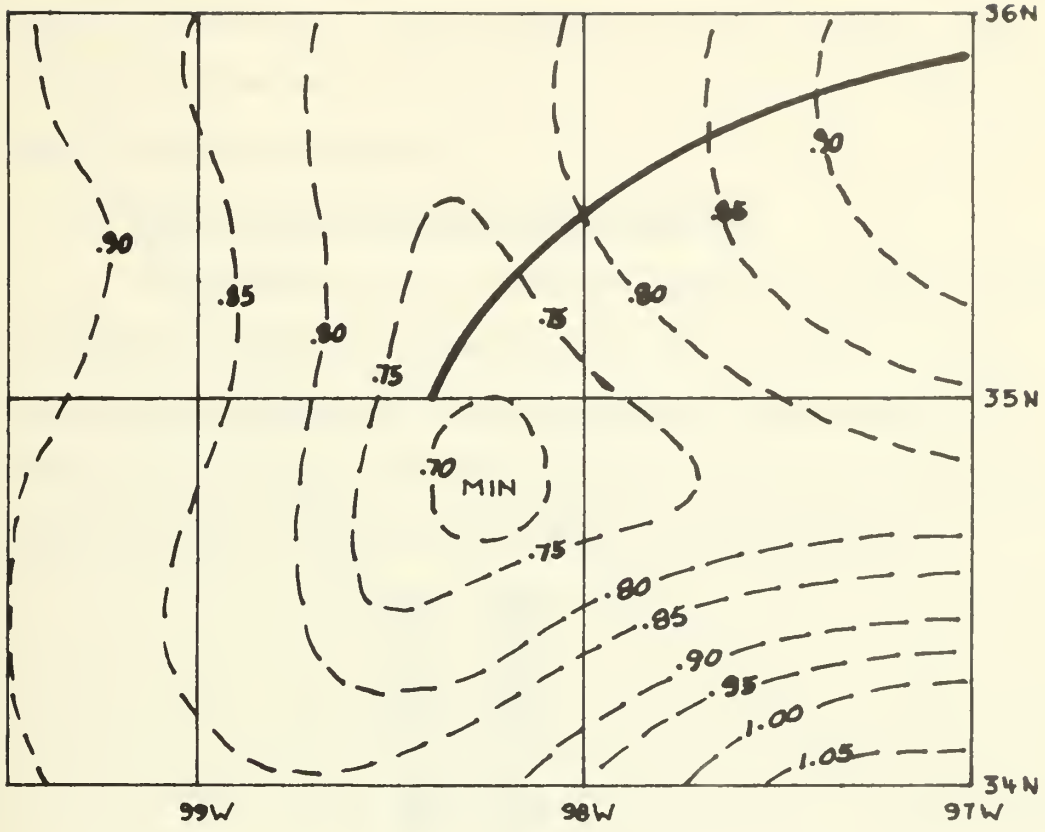


Figure 2a, 320K Theta surface, 2000 GMT Montgomery stream function analysis (add 320,00 to each value), Heavy solid line represents region of storm activity, Values in joules gm^{-1},

conducted from the isentropic kinematic trajectories. The incorporation of adjustments for changes in Montgomery stream function is a separate subroutine in the program so, if only kinematic trajectories are desired, the subroutine can be left out. The programming is included in Appendix B.

B. MODIFICATIONS FOR SEVERE STORM RESEARCH

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where ζ_θ is the absolute vorticity, D_θ the horizontal divergence, A_θ the stretching deformation, B_θ the shearing deformation, and σ the static stability. Also the height (z), specific humidity (q), saturated specific humidity (q_s) and temperature (T) fields for each isentropic surface and data time were determined. Along each kinematic trajectory the initial and final values of specific humidity, saturated specific humidity, divergence, absolute vorticity, Montgomery stream function, kinetic energy, total energy, static stability, and

Pressure analyses on each theta surface exhibited sporadic patterns. There was no real evidence of vertical consistency with regions of high or low pressure, and no time dependency as to movement or preservation of any defined center. There were large pressure ranges in the grid area on the 308K and 312K theta surfaces at 2130 and 2300 GMT (748-865 mb for 308K and 649-753 mb for 312K). These pressure ranges were a result of the decrease in height of the 308K and 312K surfaces in the SW corner of the grid at 2130 GMT and extending into the center of the grid by 2300 GMT. Pressure analyses on the 320K theta surface shows that a strong gradient existed to the SE of the storm. An example of the pressure pattern is given in Figure 2b.

An analysis of relative humidity revealed a region in the S-SE area of the network which was a minimum value area on all theta surfaces at all times (Fig. 2c). Since the storm activity occurred between upper air network stations, there was no clear indication of a region of high relative humidity. A moist or dry tongue was not evident from the relative humidity analyses.

There was a region of higher wind speed in the NW corner of the grid area and lower wind speeds in the SE corner (Fig. 2d) on all theta surfaces. This wind maximum propagated toward the east with time and increased in intensity until 2300 GMT when the speed began to decrease.

Wind direction was generally anticyclonic in the SE area and cyclonic in the NW region with a shear line along the thunderstorm activity (Fig. 2e). Time sections at stations LTS, FSI, CHK and TIK, along with the theta surface analyses of wind direction, indicated

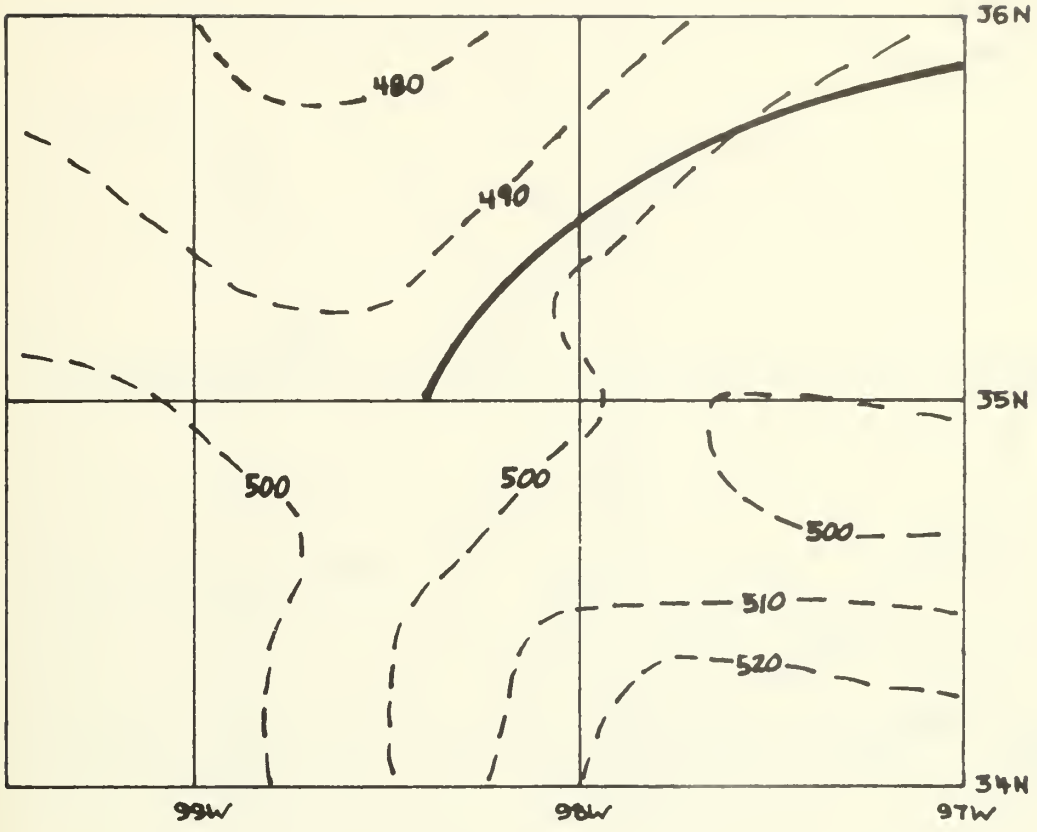


Figure 2b, 320K Theta surface, 2000 GMT pressure (mb) analysis, Heavy solid line represents region of storm activity,

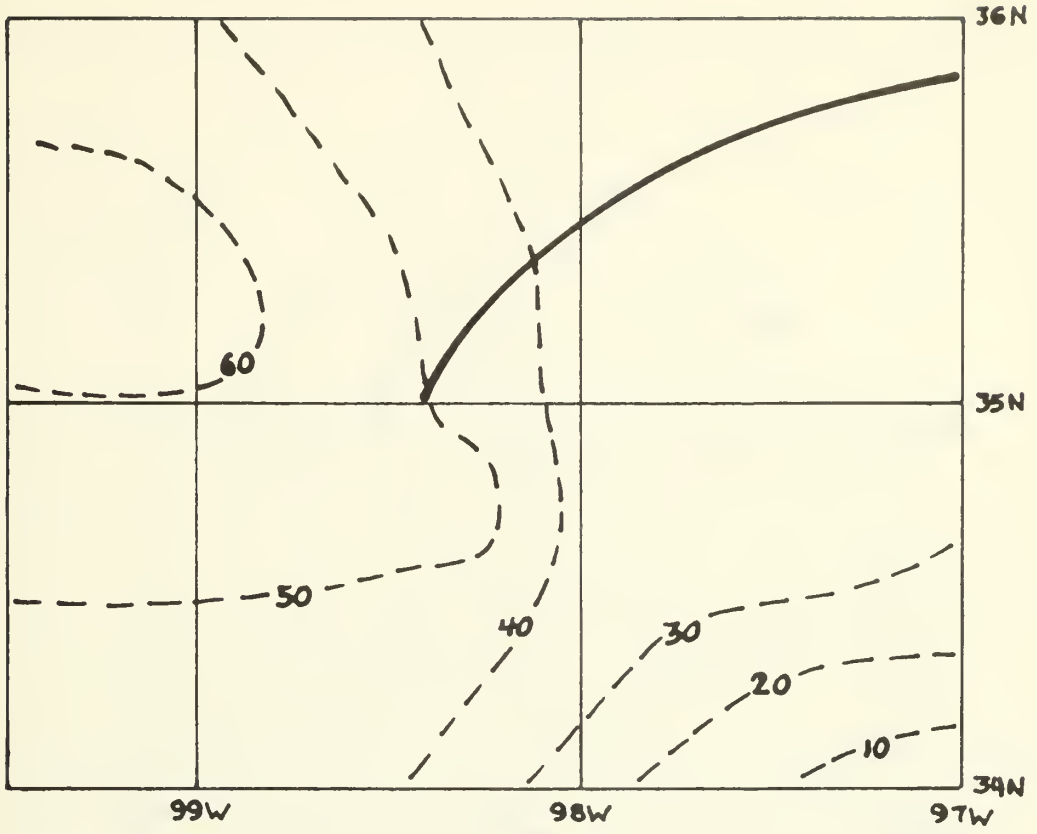


Figure 2c, 320K Theta surface, 2000 GMT relative humidity (%) analysis, Heavy solid line represents region of storm activity,

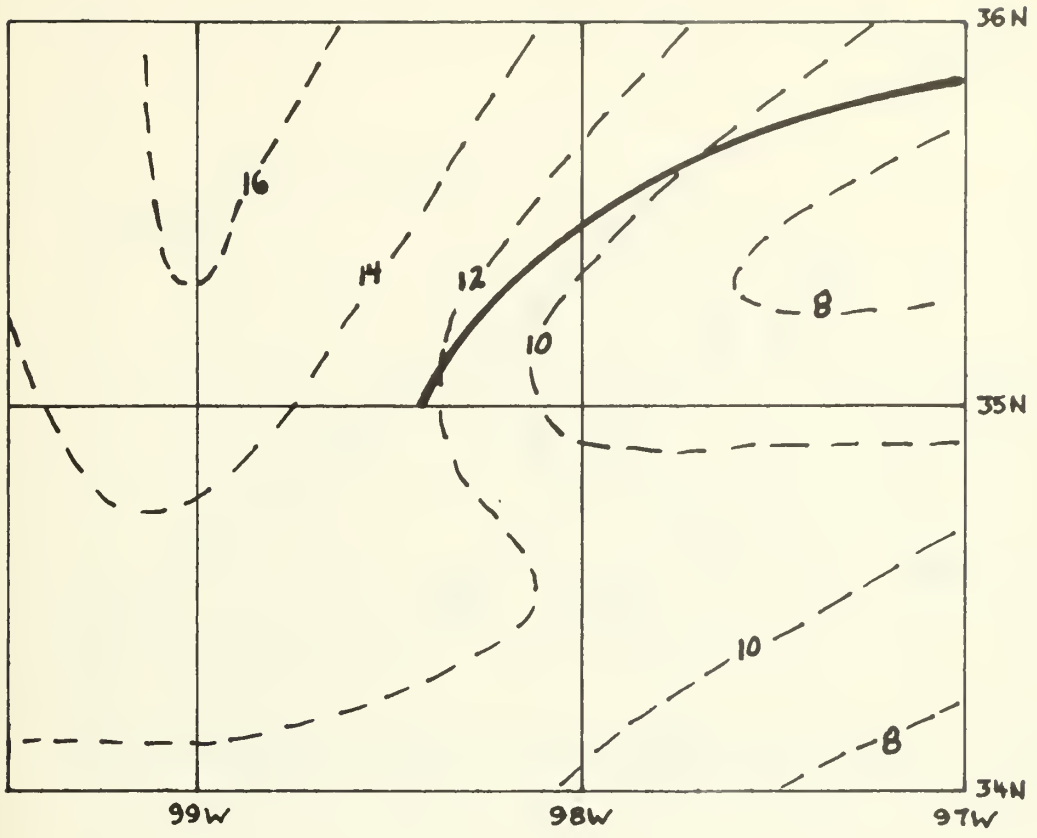


Figure 2d, 320K Theta surface, 2000 GMT wind speed (m sec^{-1}) analysis, Heavy solid line represents region of storm activity,

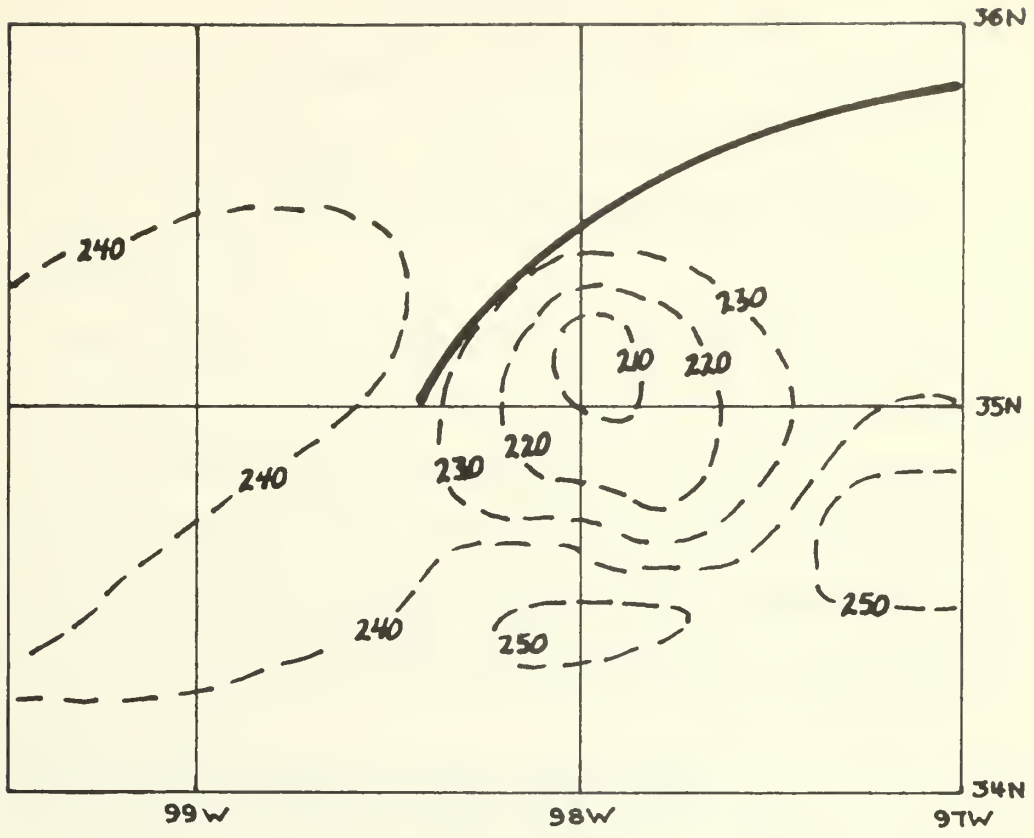


Figure 2e, 320K Theta surface, 2000 GMT wind direction (degs from north) analysis, Heavy solid line represents region of storm activity,

the wind veered with height and with time on the 308K, 312K and 320K theta surfaces. The time sections indicated the wind began to back with height above the 320K surface. This backing was evident by 1830 GMT at station LTS, by 2000 GMT at FSI, by 2130 GMT at CHK and by 2130 GMT at TIK. Wind speed at these stations generally increased with time and with height.

Data from stations LTS and FSI, which are toward the SW of the storm area, indicated the low level wind speed increased until about 2015 GMT and then began to decrease. Stations CHK and TIK, located in the SE edge of the storm region, show the wind speed continues to increase over the whole time period (1700-2300 GMT). Both the veering with height and speed increase have been correlated with severe storm activity (Miller, 1967).

B. TRAJECTORY RELATIONSHIPS TO THE SEVERE STORM

The kinematic isentropic trajectories were computed for one and one-half hour time periods at each grid point and on each theta surface. For reference to the trajectories that are discussed, see Appendix A.

The 1700-1830 GMT trajectories clearly show veering with height and time in the wind field. The 308K and 312K trajectories indicate anticyclonic flow over the whole grid, whereas the 320K and 332K trajectories have cyclonic flow in the W-NW corner and anticyclonic flow in the S-SE area. This is the flow pattern just prior to the storm formation, since the thunderstorm did not appear on radar until about 1817 GMT.

The 1830-2000 GMT trajectories imply changes in the wind field that are significant. On the 308K surface, the trajectories are beginning to have cyclonic flow in the W-NW, with a shear line almost

along the line of thunderstorm activity. The 312K trajectories specify anticyclonic flow over the whole area. The 320K surface flow pattern exhibits cyclonic flow along the south edge of the storm area, anticyclonic flow to the north, and straight flow along the center line of the storm activity. The 332K trajectory pattern denotes cyclonic flow to the SW and along the southern edge of storm activity, with anticyclonic flow in the NW and SE grid area. The storm appears to be oriented along the 320K trajectory flow pattern over this 1830-2000 GMT time frame.

During the time interval 2000-2130 GMT, the storm was in its most intense stages. It appears to be more oriented along the 308K flow pattern, which is from the south and cyclonic over most of the grid. The area to the west of the storm is strongly cyclonic. The 312K trajectories indicate straight SW flow. The 320K trajectories give evidence of a cyclonic area just to the south of the more intense regions of the storm. The 332K trajectories display anticyclonic flow over the entire grid. There is a veering of 70 degrees or more between the 308K and 320K trajectories over this period and pronounced backing in the NW region between the 320K and 332K surfaces.

Radar presentations indicate the dissipation of the storm over the 2130-2300 GMT period. The 312K trajectories are from the SW and show slight anticyclonic turning. The 320K and 332K trajectories indicate a slight cyclonic turning in the western portion of the grid and anticyclonic turning in the eastern portion. Strong backing of 45 degrees or more with height is evident between the 320K and 312K trajectory patterns.

Selected composite trajectories were obtained from each time interval in order to investigate air parcel flow over the whole time period .

These trajectories and associated parameters are discussed in the following section.

C. RELATIONSHIP OF ASSOCIATED PARAMETERS TO THE SEVERE STORM

One of the most important parameters to be computed from the kinematic isentropic trajectory program was the average vertical motion distribution for each theta surface and each 1.5 hour time interval. When used alone, these average vertical motion patterns are not sufficient to describe the storm activity. However, they do provide very definite clues to the storm dynamics when used in conjunction with other properties.

During the time interval 1700-1830 GMT, the vertical distribution of vertical motions over the NSSL network indicated lower level air parcel sinking in the western half of the grid of about 8 mb hr^{-1} and rising motions of 10-20 mb hr^{-1} in the eastern half of the grid. Upper level patterns were reversed, with rising motions in the western half and sinking motions in the eastern half. In addition, there was very strong rising motion (20-30 mb hr^{-1}) in the western half of the grid at a height of about 10 KM. It is possible that the high level vertical motion pattern is the initial indication of an upper level formation of supporting vertical motions for the storm.

The 1830-2000 GMT vertical motion patterns (Fig. 3a-3d) clearly delineate and support the storm system. At each level there is strong rising motion as air parcels come into the storm area, with sinking motions over the remaining grid area. The 320K isentropic surface vertical motion pattern indicates the region of maximum rising motion. The storm is also oriented parallel to the 320K trajectory flow pattern over this period. It would appear the 320K (i.e. approximately 500 mb) flow is responsible for maintaining the storm at this time.

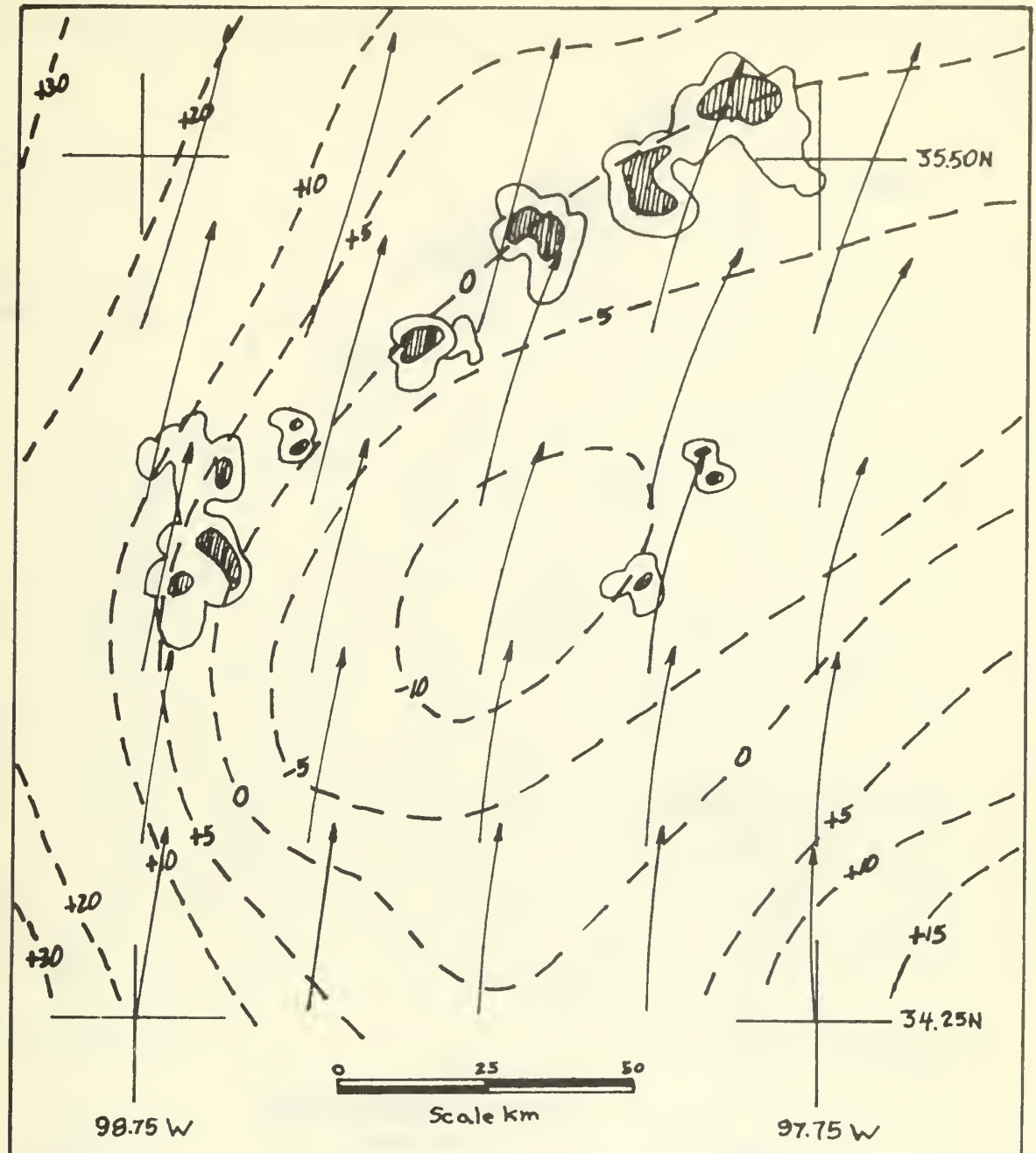


Figure 3a, 308K Theta surface, 1830-2000 GMT average vertical motions (mb hr^{-1}) and kinematic isentropic trajectories, Storm position as of 1915 GMT,

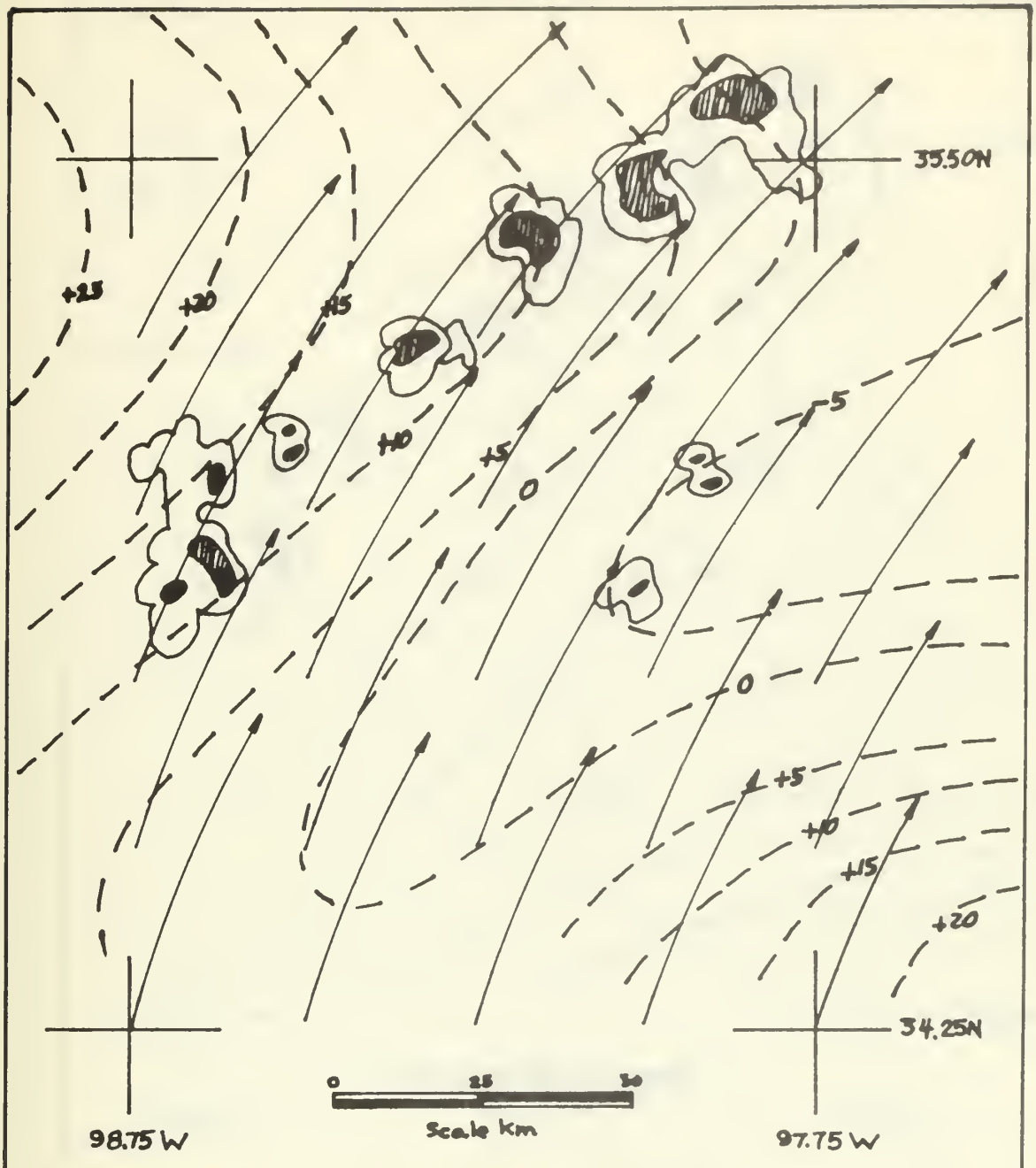


Figure 3b, 312K Theta surface, 1830-2000 GMT average vertical motions (mb hr^{-1}) and kinematic isentropic trajectories, Storm position as of 1915 GMT,

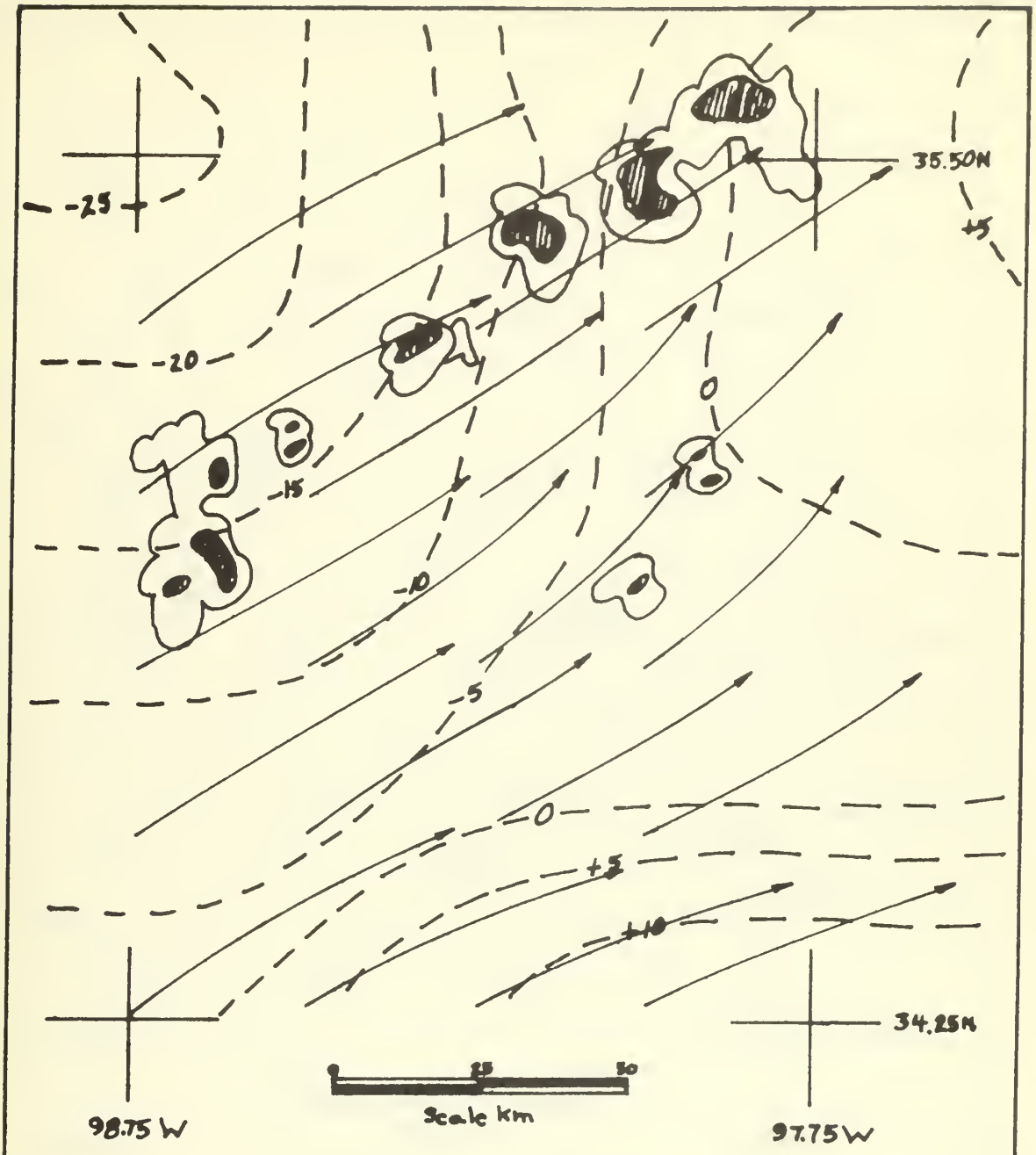


Figure 3c, 320K Theta surface, 1830-2000 GMT average vertical motions (mb hr^{-1}) and kinematic isentropic trajectories, Storm position as of 1915 GMT,

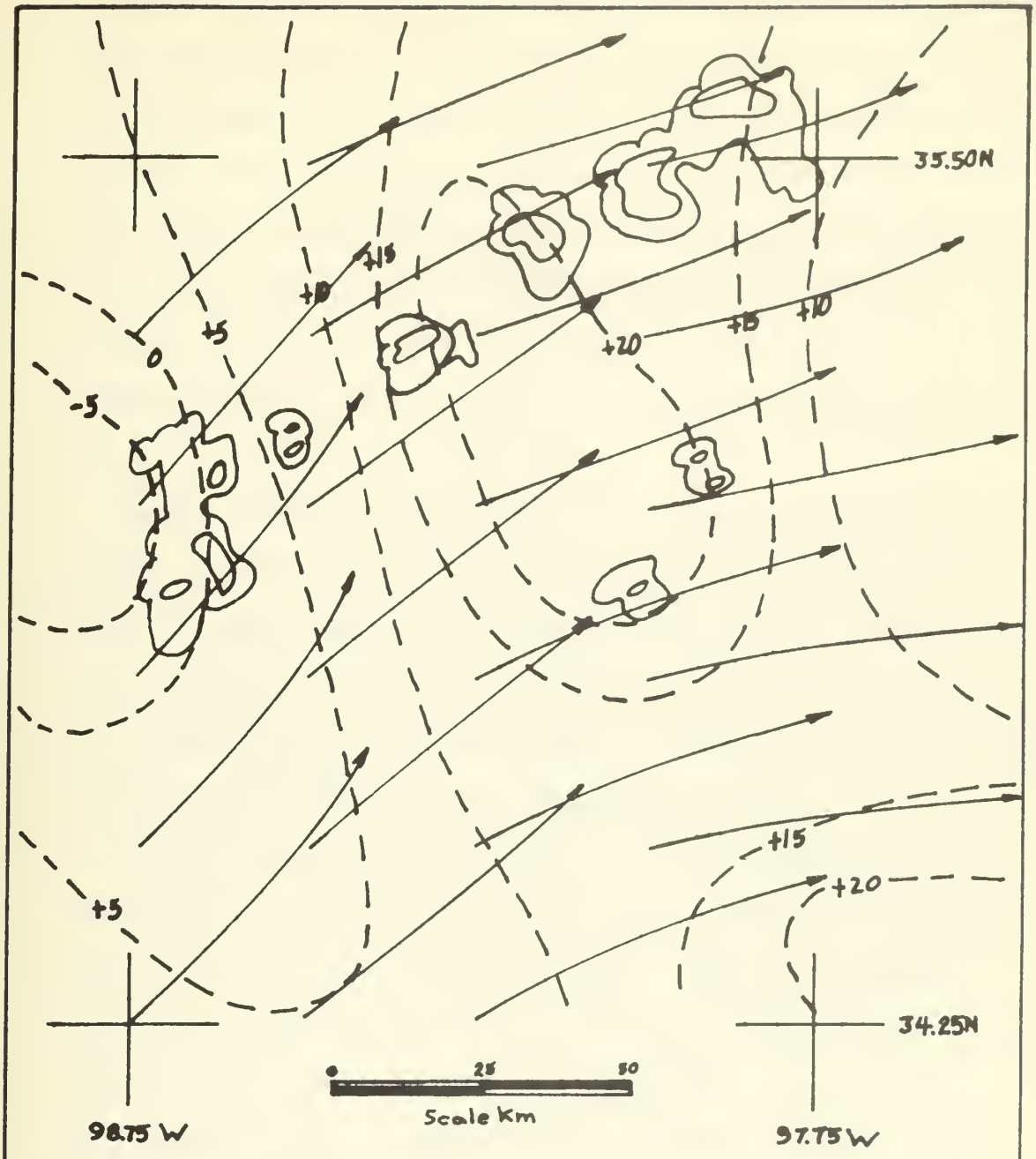


Figure 3d, 332K Theta surface, 1830-2000 GMT average vertical motions (mb hr^{-1}) and kinematic isentropic trajectories, Storm position as of 1915 GMT,

Over the 2000-2130 GMT period the 308K and 312K isentropic surfaces vertical motion patterns present sinking motion over most of the grid, with larger values (25-30 mb hr^{-1}) in the northern half of the grid. The 320K and 332K theta surfaces vertical motions still show rising in front and into the storm system, but the patterns are not as well defined. The 2000-2130 GMT convergence fields on the 320K isentropic surface are well correlated with the storm system and show strong convergence of 1.0 to 1.5 x 10^{-4} sec^{-1} in the system (Figs. 4a, 4b).

Darkow (1968) has examined the total energy environment of severe storms on the synoptic scale of motion and has determined a "Total Energy Index". This index is computed as the difference between the "total energy" ($c_p T + gz + Lq$) at 500 mb and the total energy at 850 mb. Index values more negative than -2.0 cal gm indicate severe storms and associated tornado activity are highly probable.

The NSSL isentropic plane section computer output for the nine radiosonde stations gives the static energy. This data was investigated in terms of a "Total Energy Index". Values at 1700 GMT indicated a region of -2.0 in the area where the thunderstorms began to occur. Values in the same region were -4.0 or larger by 2000 GMT (Fig. 5). Values over the remaining grid area were slightly negative or positive.

Total energy, defined by equation (8), was investigated for storm evolvement. The 312K and 320K isentropic surfaces for the 2000 and 2130 GMT analyses show a region of maximum total energy in the storm vicinity, with decreasing values toward the NW and SE. This region is seen in Figure 6. As shown by Figure 7, the contour pattern of total energy closely resembles the specific humidity distribution, which

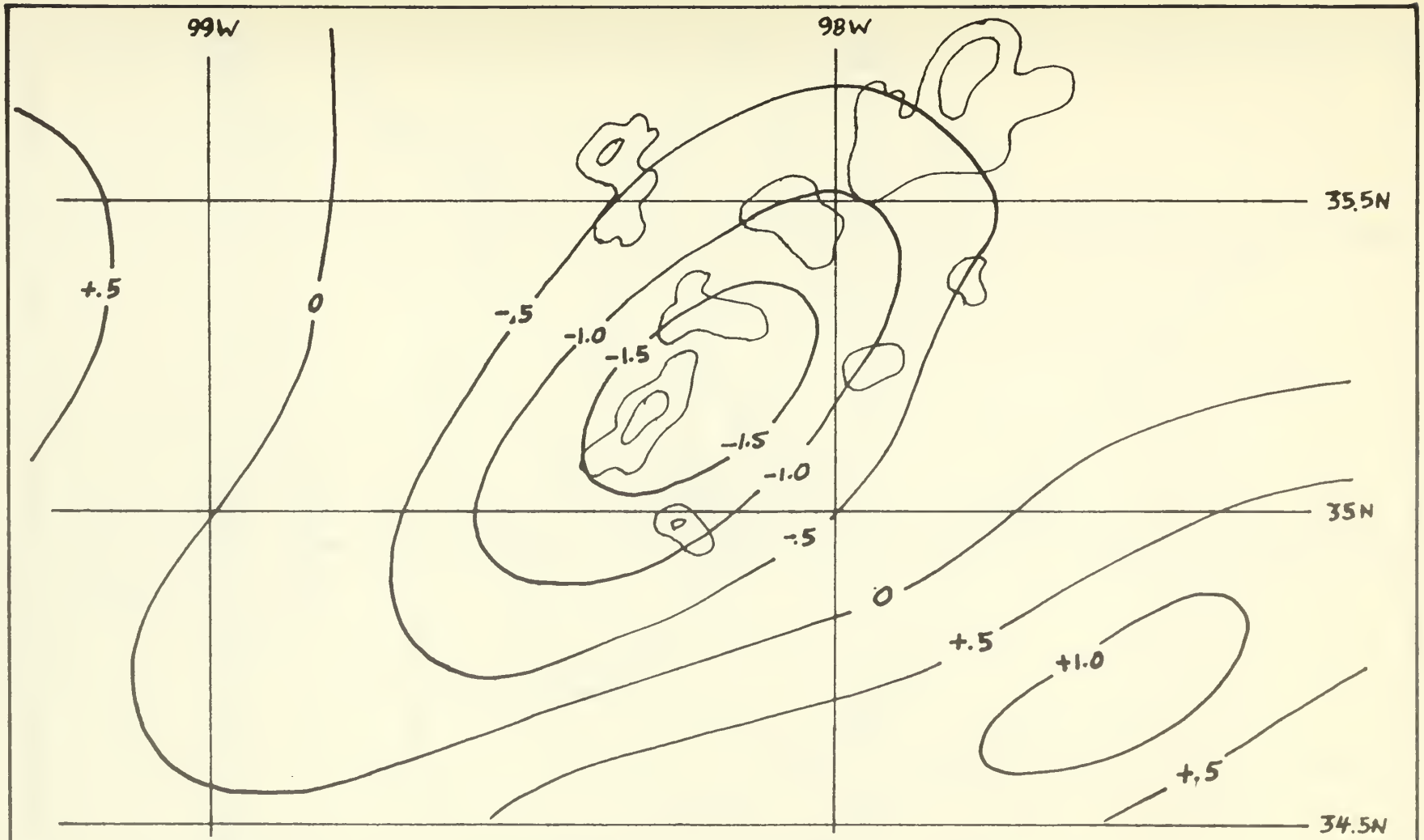


Figure 4a, 320K Theta surface, 2000 GMT convergence (10^{-5} sec^{-1}),

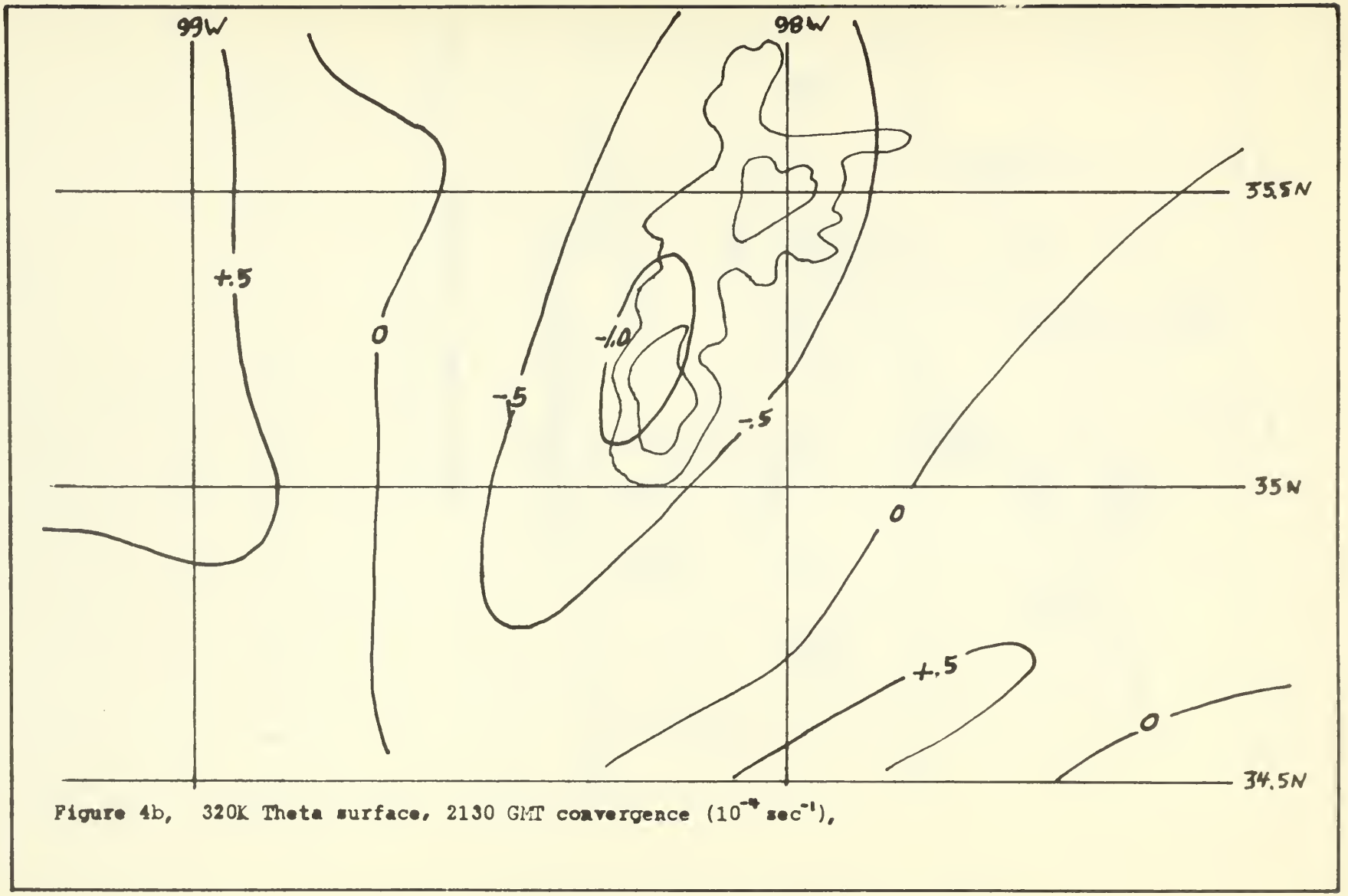


Figure 4b, 320K Theta surface, 2130 GMT convergence (10^{-5} sec^{-1}),

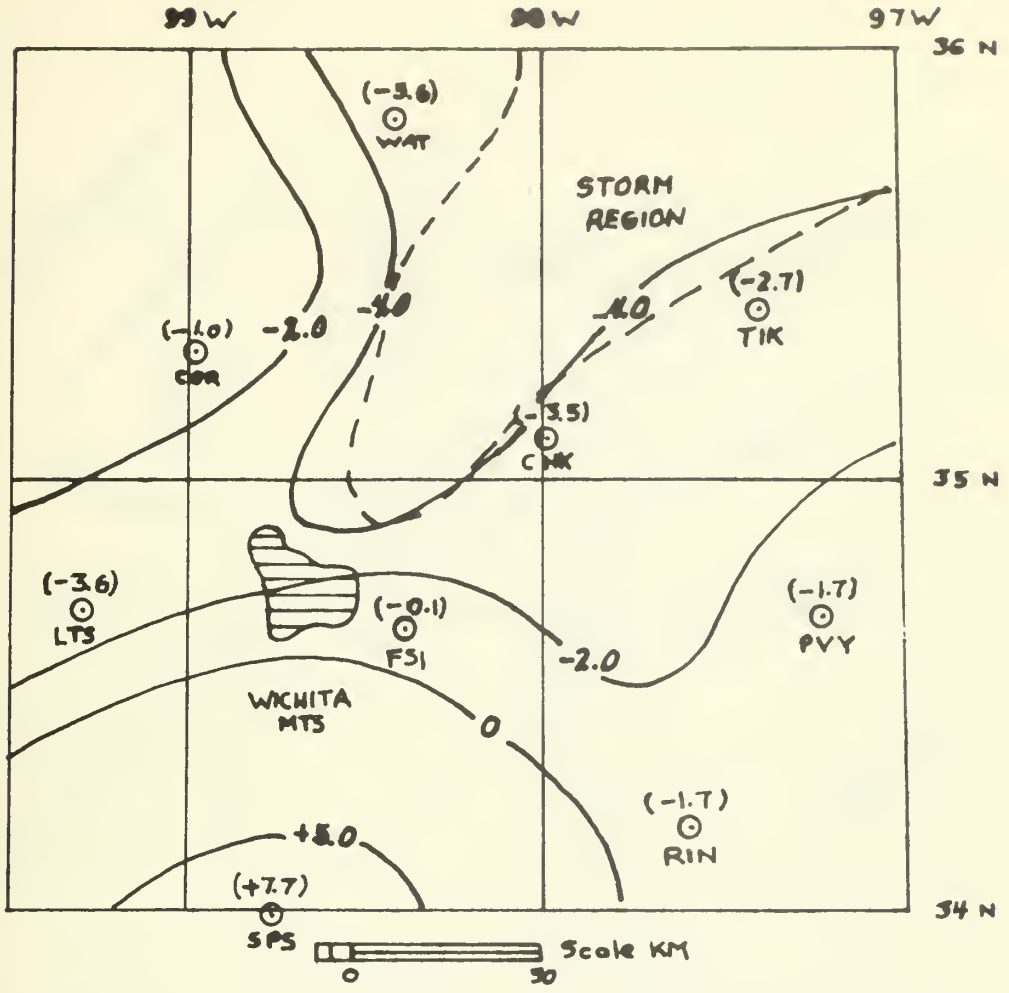


Figure 5, 2000 GMT Total energy index,

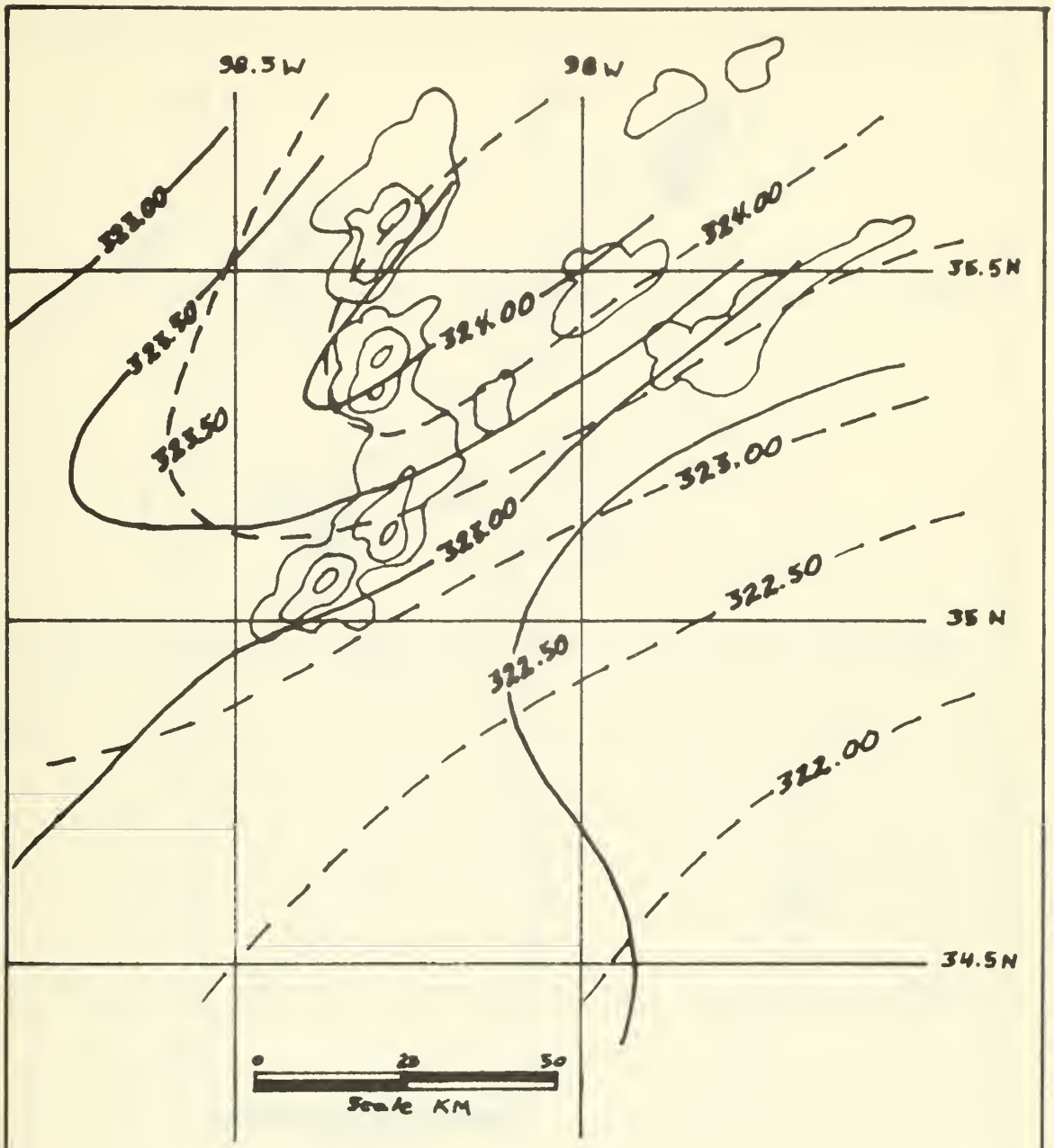


Figure 6, 320K Theta surface total energy (joules gm^{-1}) analysis, Solid lines are 2000 GMT pattern and dashed lines are 2130 GMT pattern, Storm position as of 2045 GMT,

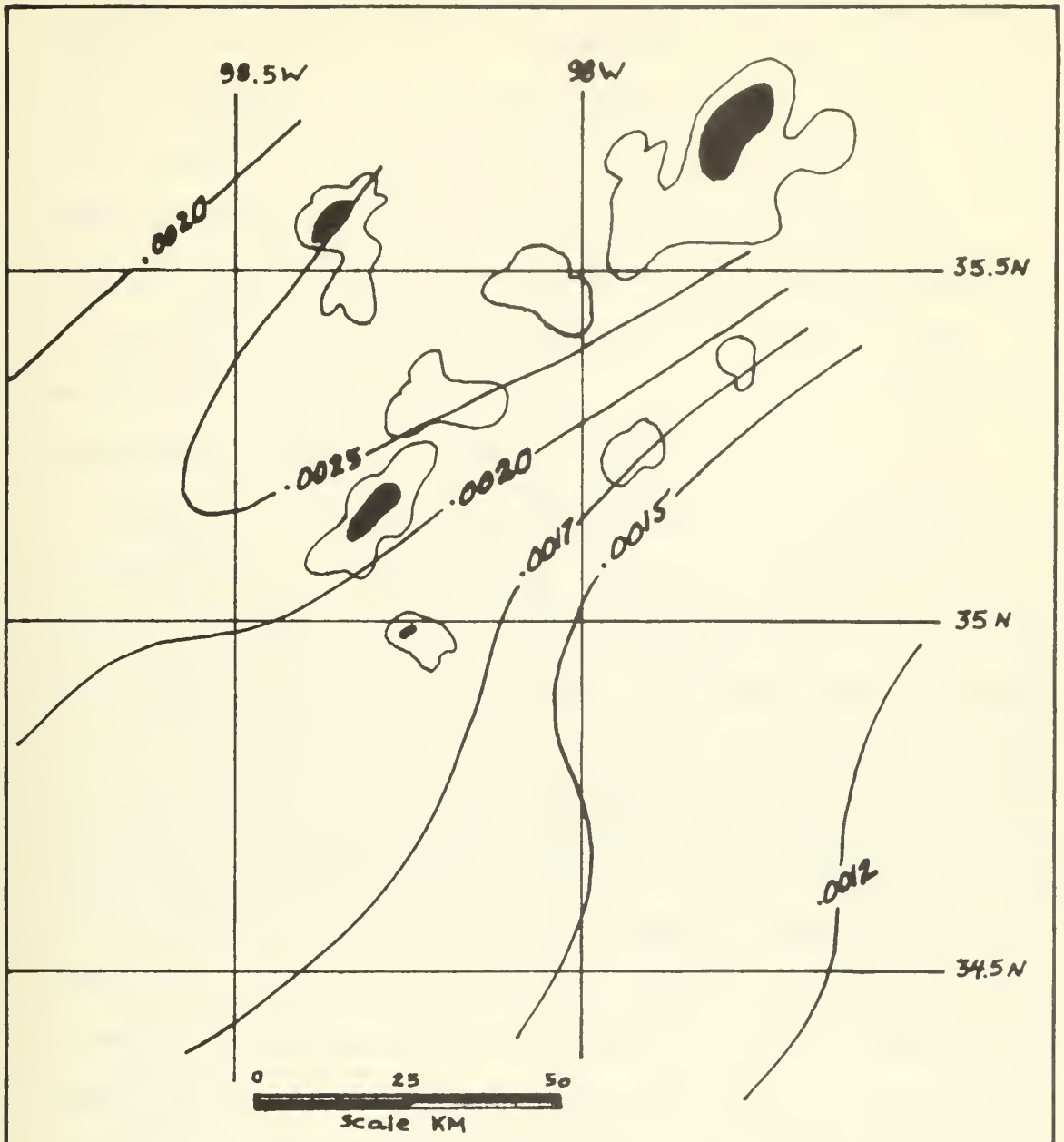


Figure 7, 320K Theta surface, 2000 GMT specific humidity (gm gm^{-1}) distribution,

indicates the Lq term dominates the pattern. Thus the relative humidity analysis is a critical factor in determining the total energy. The relative humidity is not the most reliable information from a radiosonde sounding, particularly at higher altitudes. Since the Lq term seems to dominate the total energy contours, unless the relative humidity field is adequately specified, the total energy computations will not provide good information with which to study the storm. There are also inaccuracies in the Montgomery stream function field which may amplify the error in total energy computations.

Fankhauser (1968) has demonstrated the wind field relationship for this same May 28, 1967 storm system. Using chaff trajectories and aircraft measurements, the streamline and isotach pattern of the composite relative wind field with respect to the storm echo are presented (Fig. 8). The 320K isentropic surface almost corresponds with the 500 mb isobaric surface, thus a good comparison can be made. In Figure 9 the isentropic trajectories show that flow is being deviated around the storm, convergence into the storm and divergence behind the storm. The acceleration field (Fig. 10) also shows maxima to the right and left of the storm and minima in front of and behind the storm. Fankhauser has demonstrated the flow for an isolated storm echo and the fields are instantaneous. The isentropic trajectories show average conditions for the larger storm system, and yet the results are strikingly similar. The comparison times are also different, which may indicate this wind distribution is present throughout the storm cycle for both isolated cells and the entire storm complex. Thus the 1.5 hour kinematic isentropic trajectories correlate very well with the chaff trajectories that Fankhauser has obtained.

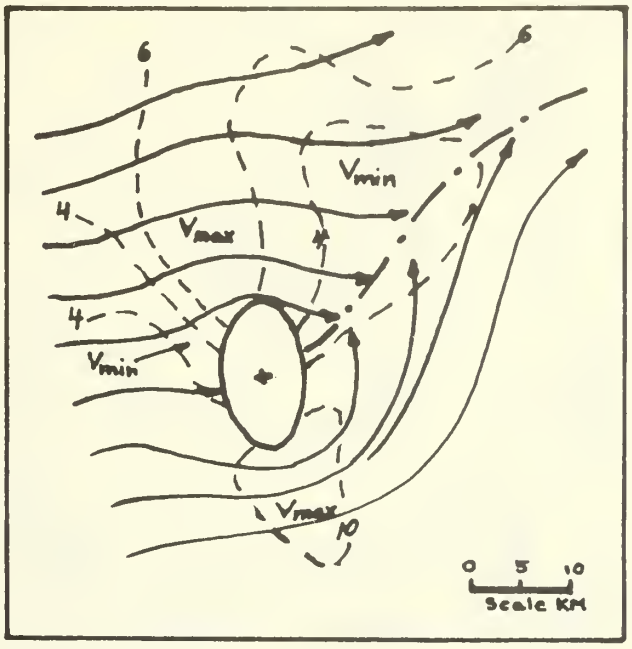


Figure 8, 2145 GMT simplified streamline and isotach pattern relating the composite relative wind field with respect to storm echo centered on cross, (after Fankhauser, 1968, fig, 8), Wind speeds in m sec^{-1},

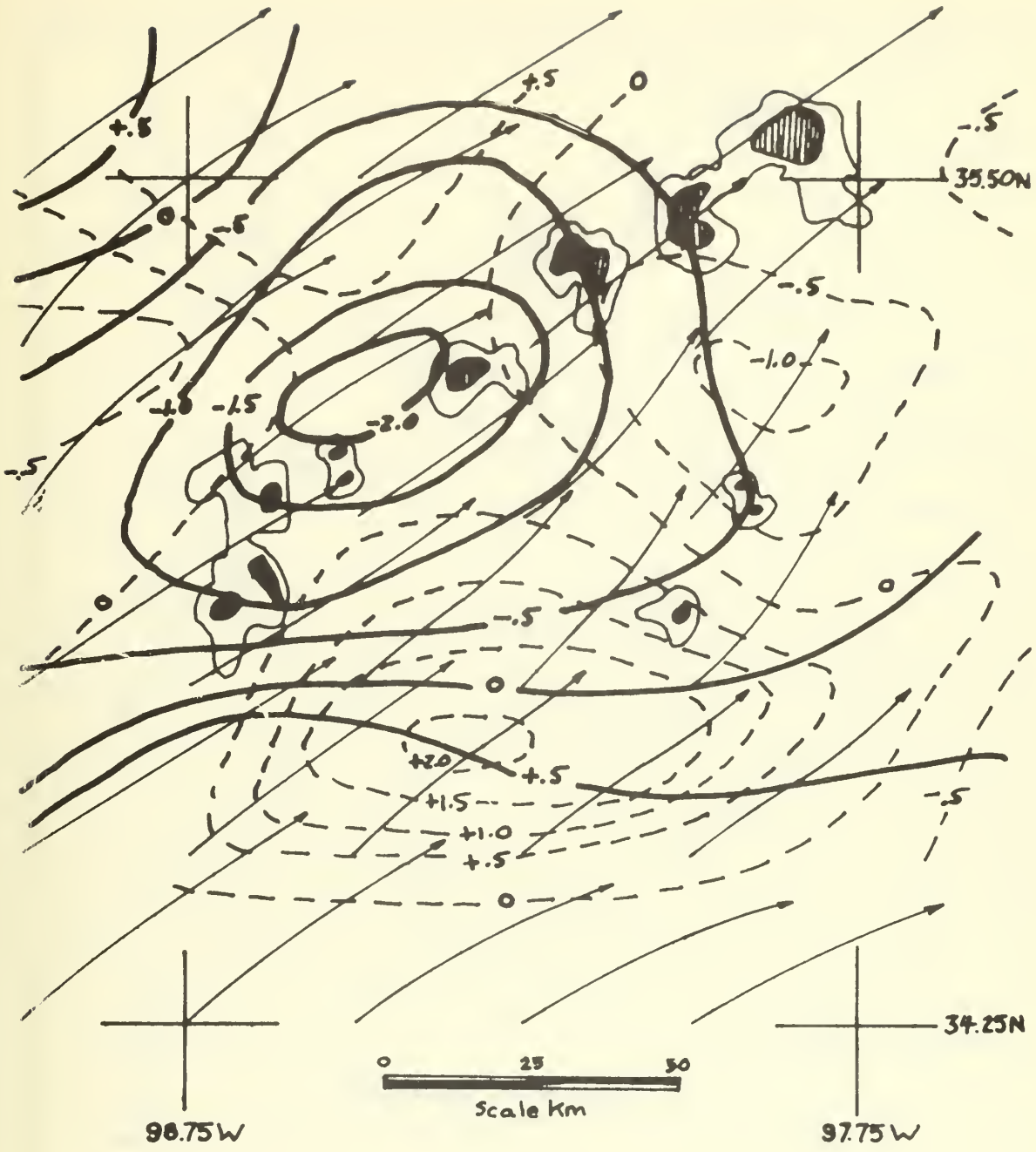


Figure 9, 320K Theta surface, 1830-2000 GMT kinematic isentropic trajectories relative to the storm, Dashed lines represent changes in absolute vorticity (10^{-5} sec^{-1}) computed along the trajectory, Heavy solid lines represent changes in divergence (10^{-5} sec^{-1}) computed along the trajectory, Storm position as of 1915 GMT,

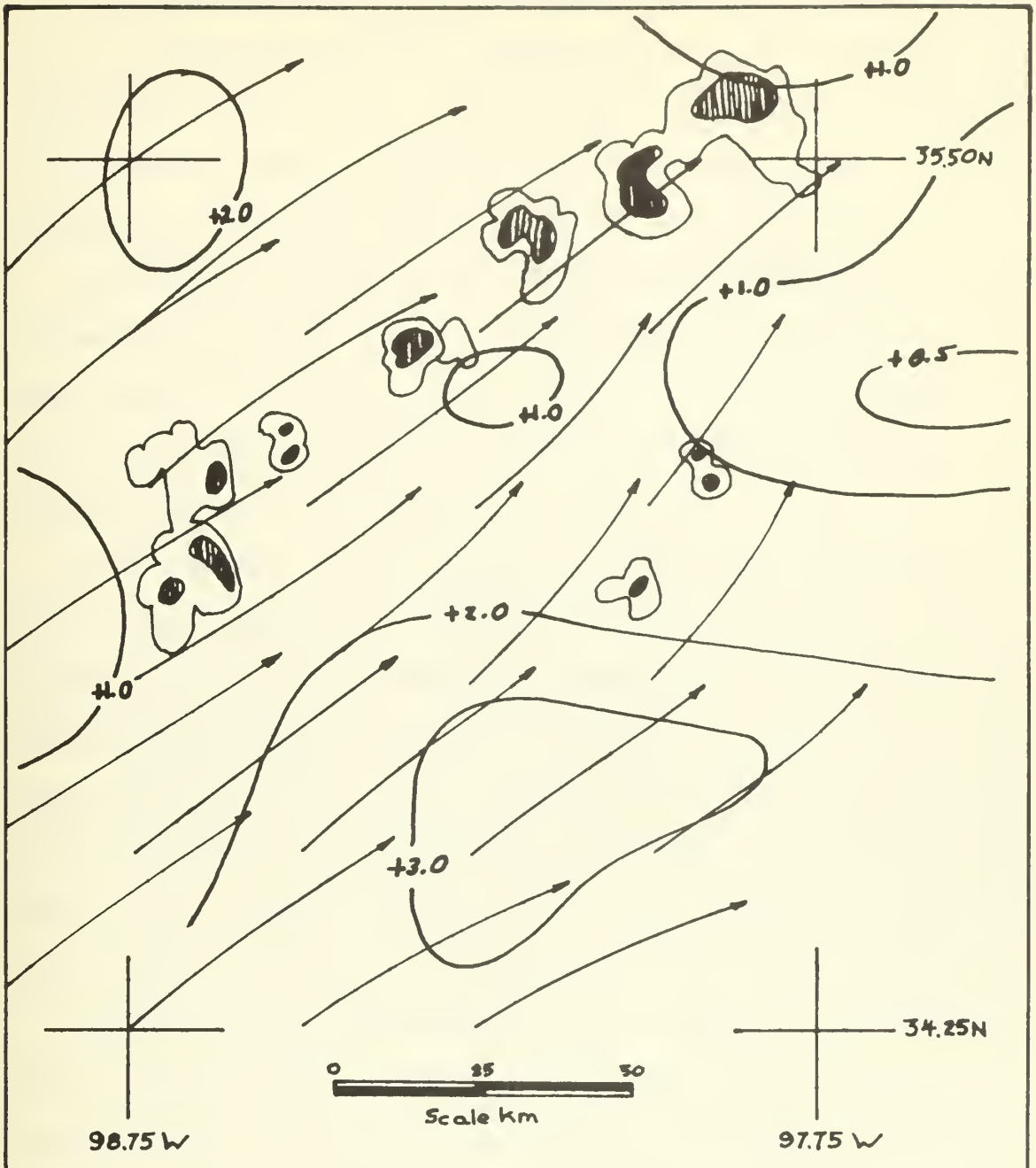


Figure 10, 320K Theta surface, 1830-2000 GMT accelerations (m sec^{-1} hr^{-1}), Storm position as of 1915 GMT,

D. INERTIAL-GRAVITY WAVE ASSOCIATION TO THE SEVERE STORM

A close look at various analyses seems to imply an oscillation present in the network area. Thus an investigation into the possibility of a wave like phenomenon present over the data area was considered as a possible source of the storm activity and storm movement.

An oscillatory tendency can be observed on the 320K theta surface composite trajectories (Fig. 11). Measurements in the center of the grid region show a wave length of about 150 KM and period of about 3 hours. Radar presentations of the most intense storm activity also indicate a wave length of about 150 KM (Fig. 12).

Surface pressure tendencies over the network area were studied to determine if the oscillation could be detected at the surface. Microbarograph traces were available at 35 stations over the data area. The pressure tendencies indicated falling pressures of about 0.03 inches of Hg per 1.5 hours over the grid during the entire life cycle of the storm. Figure 13 illustrates this tendency over the area. A noticeable fluctuation was not apparent at most stations. Even the presence of the storm was difficult to detect (see stations 3A, 3C, 4B and 4C on Fig. 13).

Synoptic pressure tendency patterns were obtained for 1800 and 2400 GMT, and a mean synoptic pressure tendency over the grid area was calculated. This value was then subtracted from the network stations pressure tendency at each time frame in order to calculate a "mesoscale pressure tendency". The results, as seen in Figure 14, indicate both rise and fall areas. The rise and fall areas show a half wave length of about 100 KM along the mean low level wind field, and a 150 KM wave length between two negative centers along a line of mean wind direction.

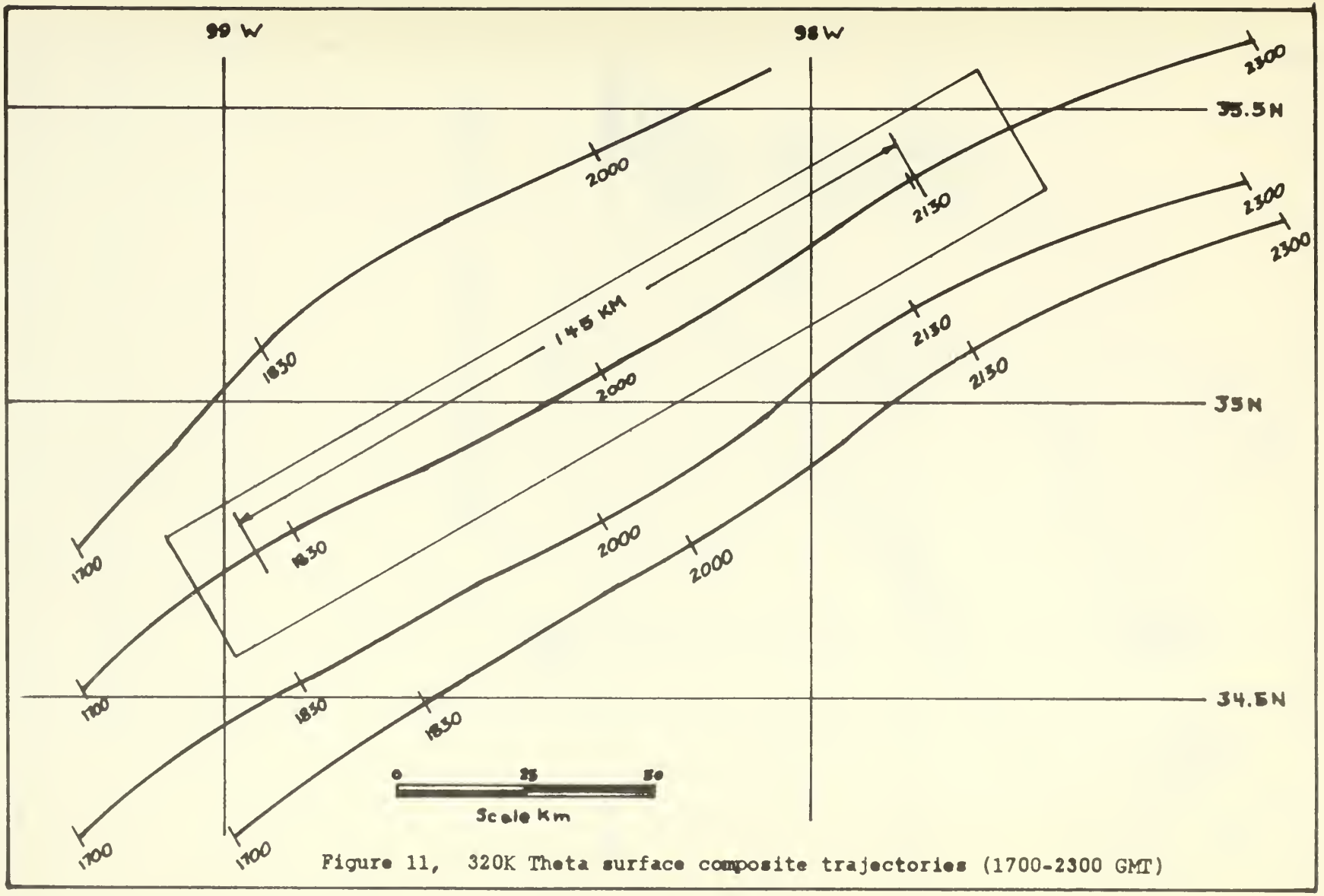


Figure 11, 320K Theta surface composite trajectories (1700-2300 GMT)

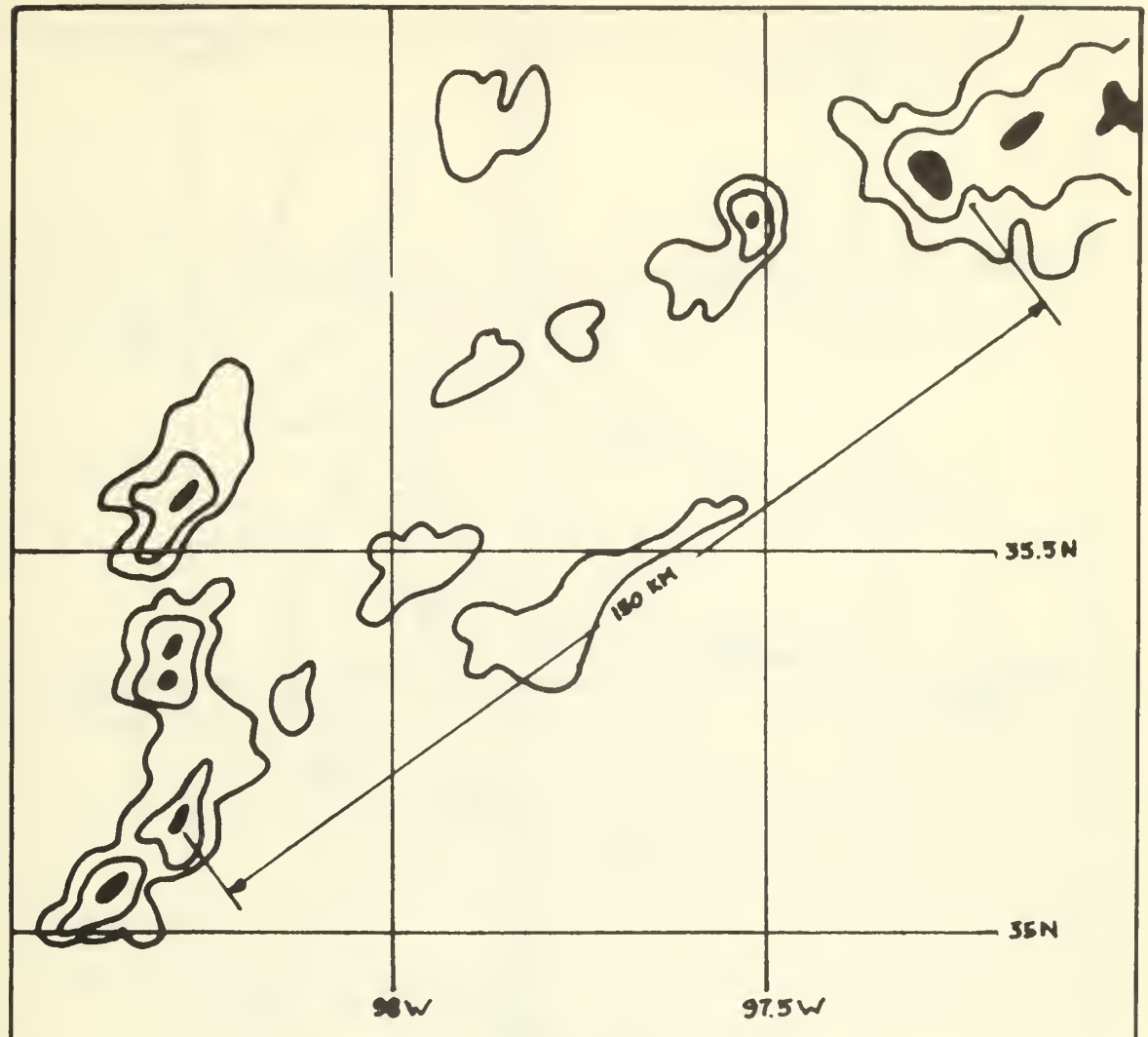


Figure 12, 2045 GMT storm position,

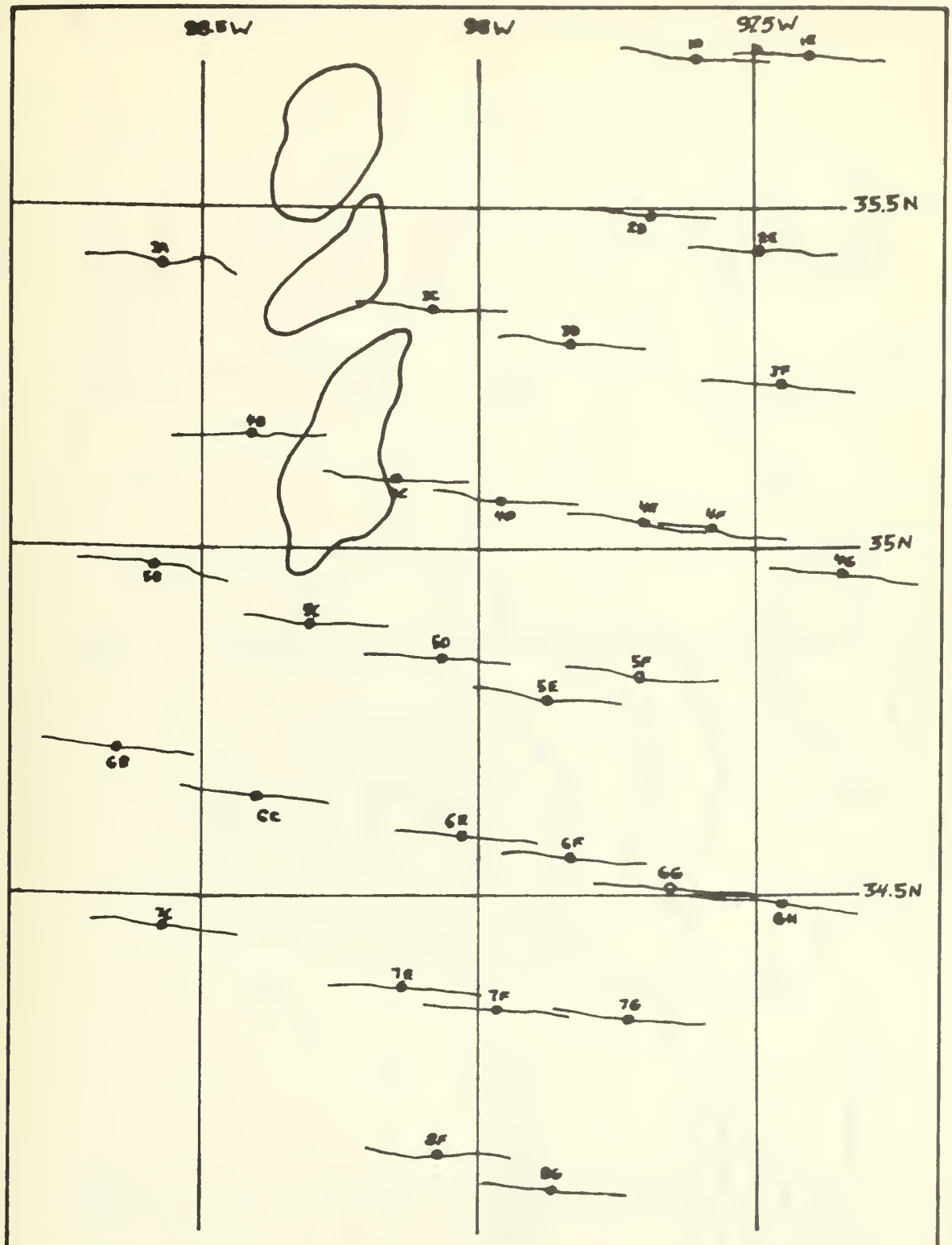


Figure 13, 2030-2130 GMT surface microbarograph traces centered at 2100 GMT on each station, Measurements in inches of Hg, 2100 GMT storm position,

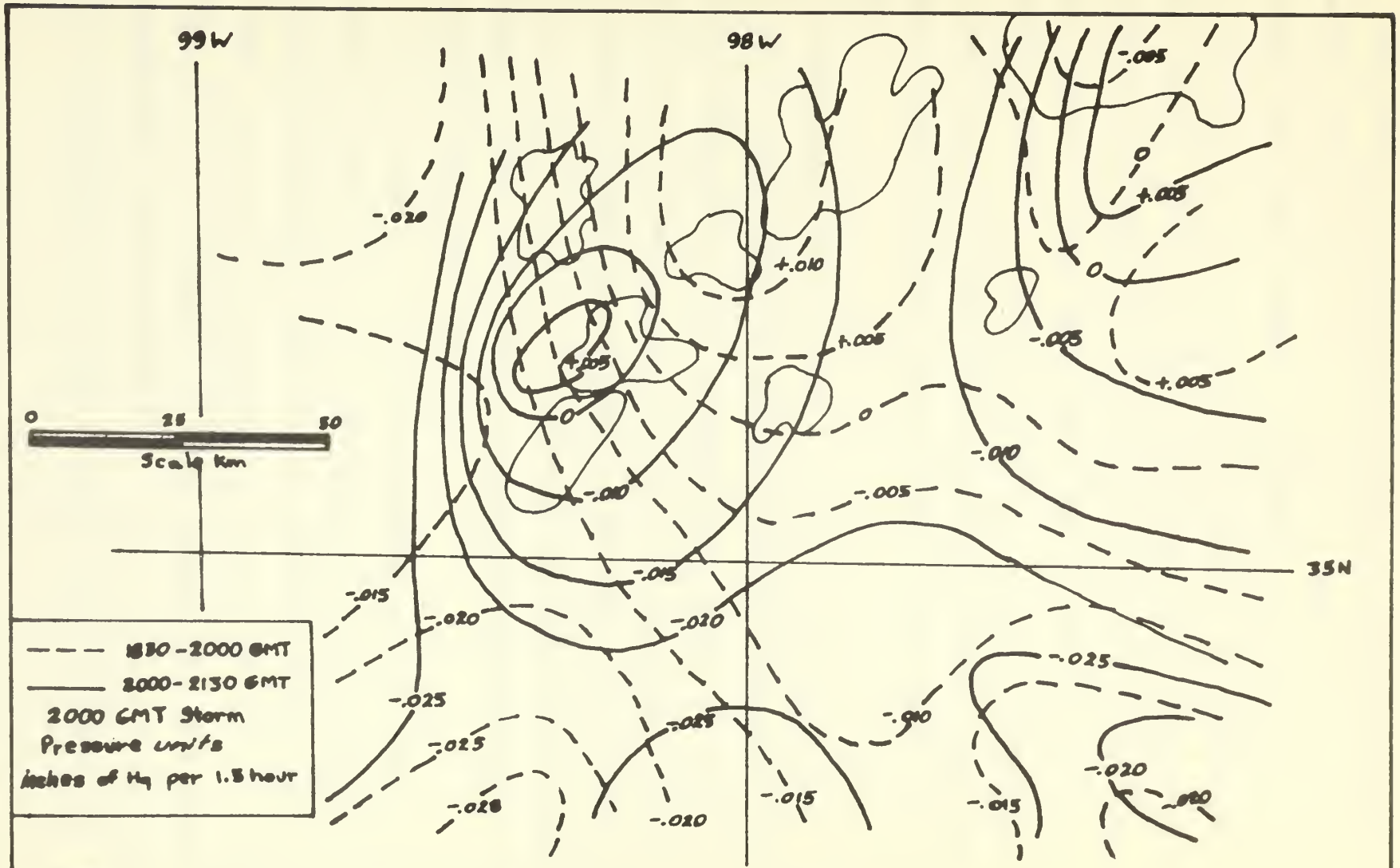


Figure 14, Mesoscale pressure tendency patterns for 1830-2000 and 2000-2130 GMT,

Time sections at selected stations along the mean wind direction (see Fig. 15) were made in order to study the time variations of vertical motion, static stability, relative humidity, wind speed and wind direction. The time sections at stations LTS, FSI, CHK and TIK (Figs. 16a-16d) indicate an apparent periodicity in the vertical motion and static stability patterns. The vertical motions are the average omega obtained by the trajectory method, and the static stability is the value centered between two adjacent theta surfaces. Measurements on these time sections, from the vertical motion patterns, give a wave length of about 150 KM, wave period of 3 hours and wave speed of 14 m sec^{-1}.

It can be seen in Figure 16a that a region of vertical motion of +30 mb hr^{-1} is occurring at station LTS at 1915 GMT, between the 308K and 312K theta surfaces. With the measured wave speed of 14 m sec^{-1} (50 KM hr^{-1}), a propagating wave without change in amplitude, constant wave length and moving in the direction of the mean wind would produce a region of about +30 mb hr^{-1} at station FSI about 2045 GMT and station CHK about 2145 GMT. This condition is verified at these stations for the specified times (Figs. 16b & 16c).

With the assumption of a wave-like phenomenon present, a study was conducted to determine if such a wave phenomenon and other supporting dynamic and thermodynamic forces could be correlated with the onset of the storm. The earliest radar presentation at 1817 GMT indicated small cumulus activity in the western portion of the grid area. Time sections at stations LTS, FSI, CHK and TIK (Figs. 17a-17b) show that at 1700 GMT there is a pronounced shift in wind direction between the stations on

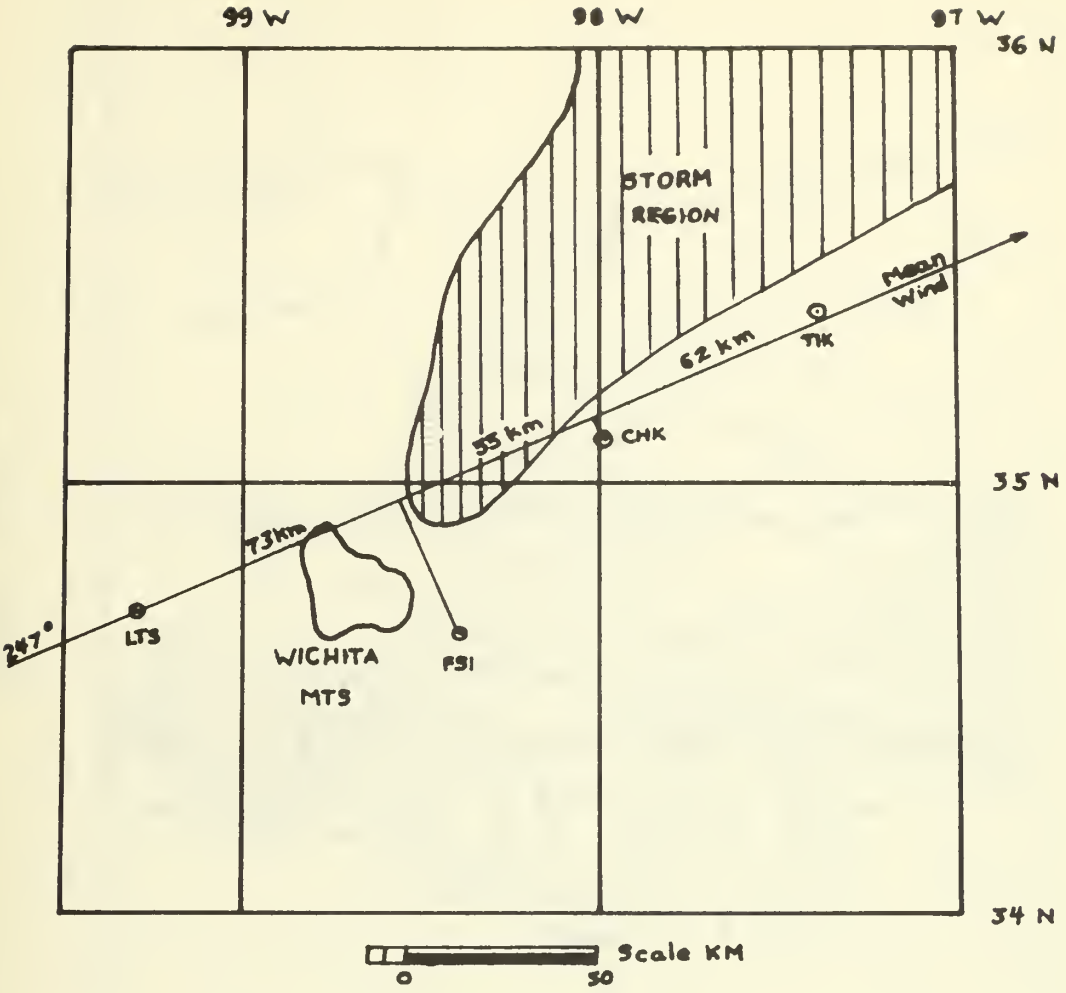


Figure 15, Station cross-section distribution for time sections,

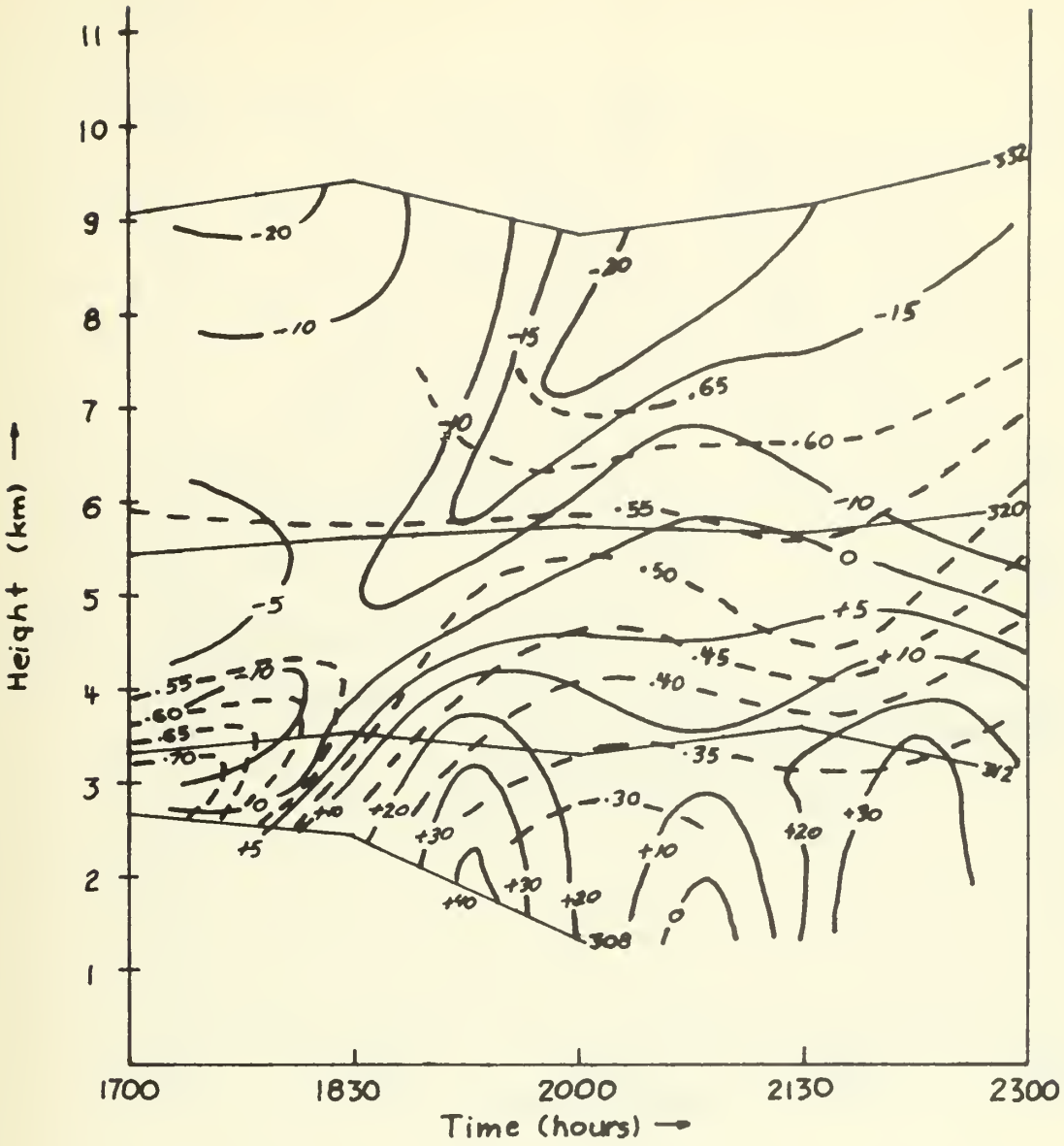


Figure 16a, Time section at station LTS, Heavy solid lines represent vertical motions (mb hr^{-1}), Dashed lines represent static stability (K mb^{-1}), Thin solid lines represent theta surface positions,

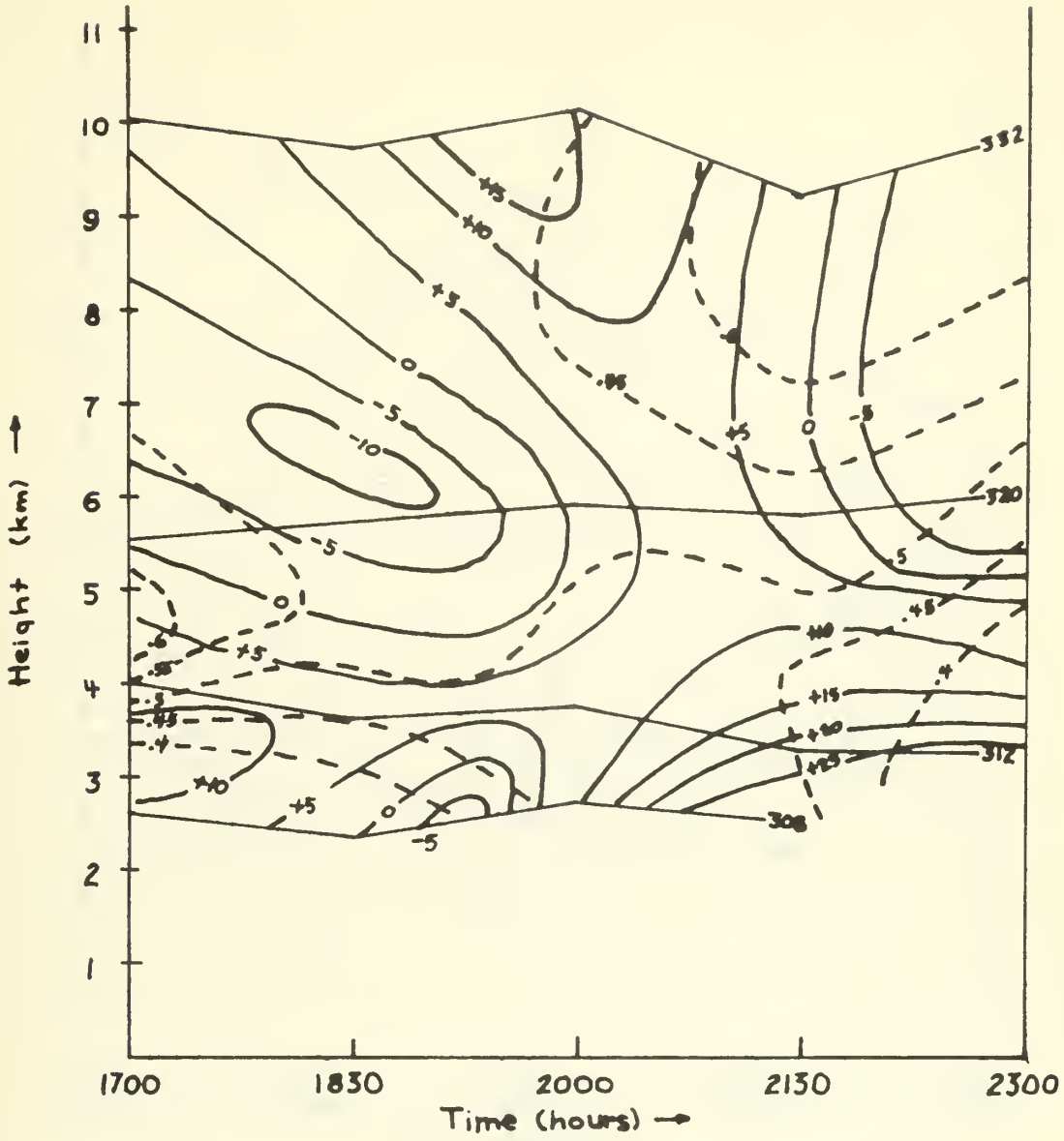


Figure 16b, Time section at station FSI, For explanation see fig, 16a,

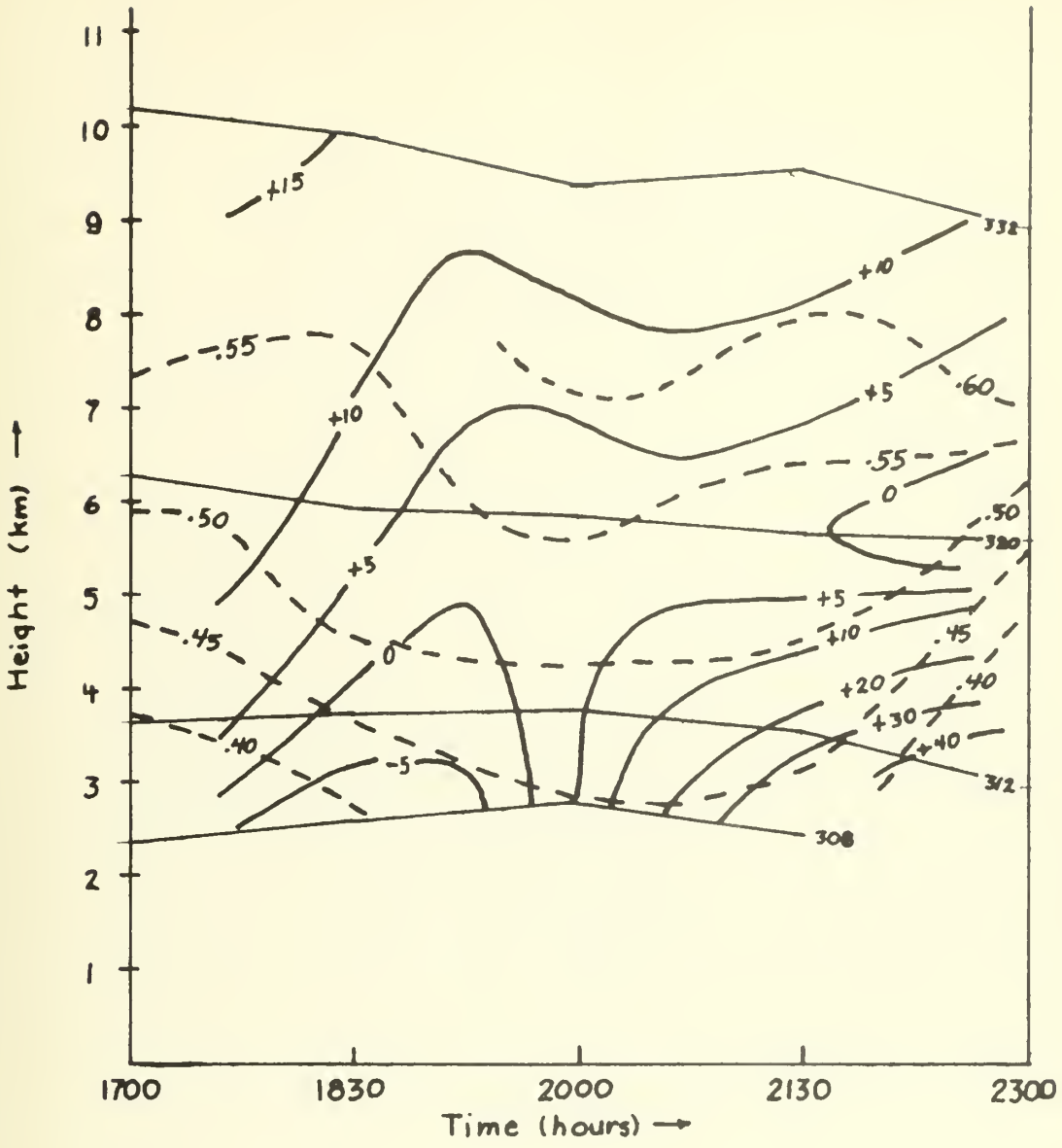


Figure 16c, Time section at station CHK, For explanation see fig, 16a,

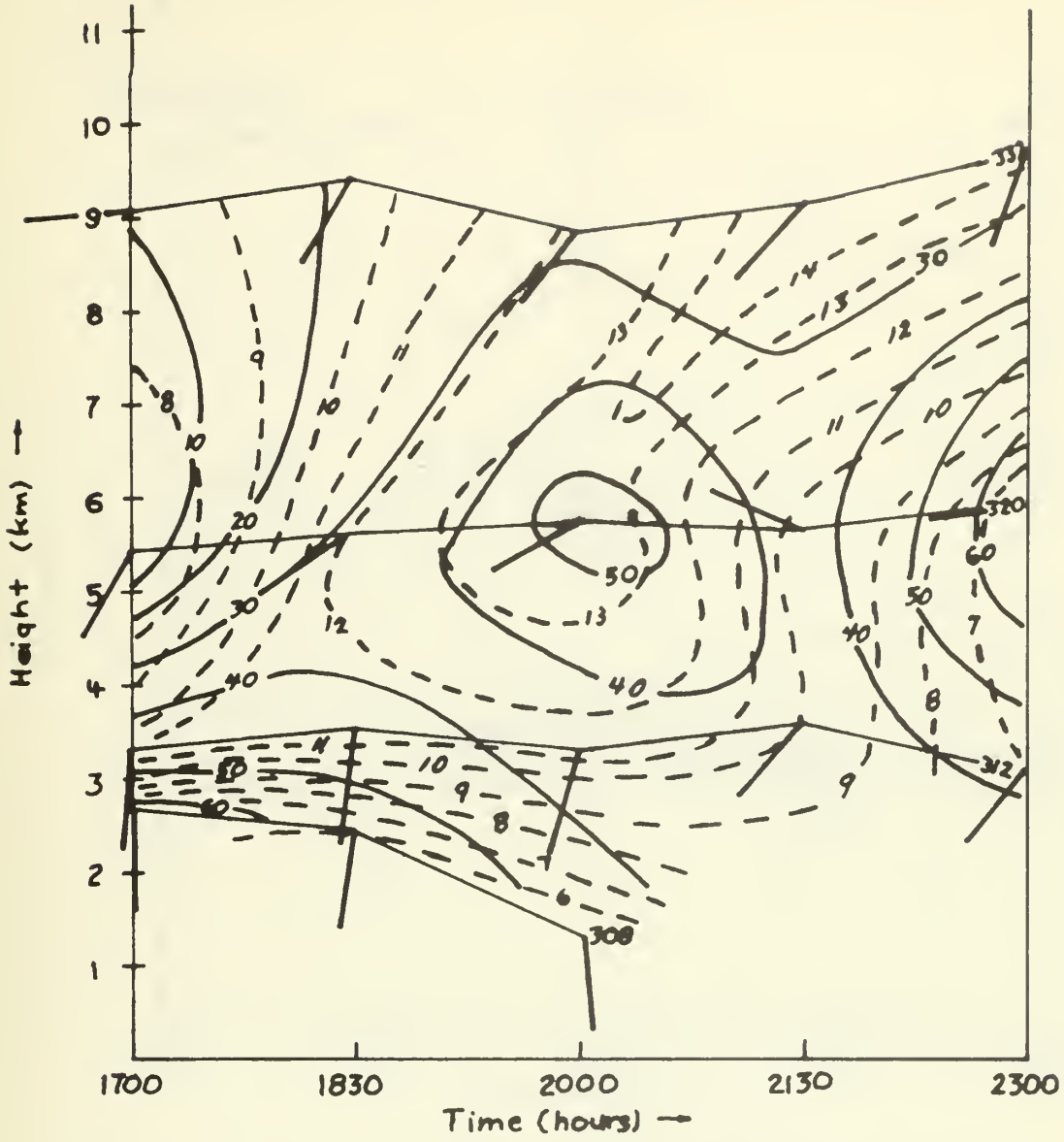


Figure 17a, Time section at station LTS, Thin solid lines are theta surface positions, Heavy solid lines are relative humidity (%), Dashed lines represent wind speed (m sec^{-1}), Short solid lines represent wind direction (360 degs at top of page),

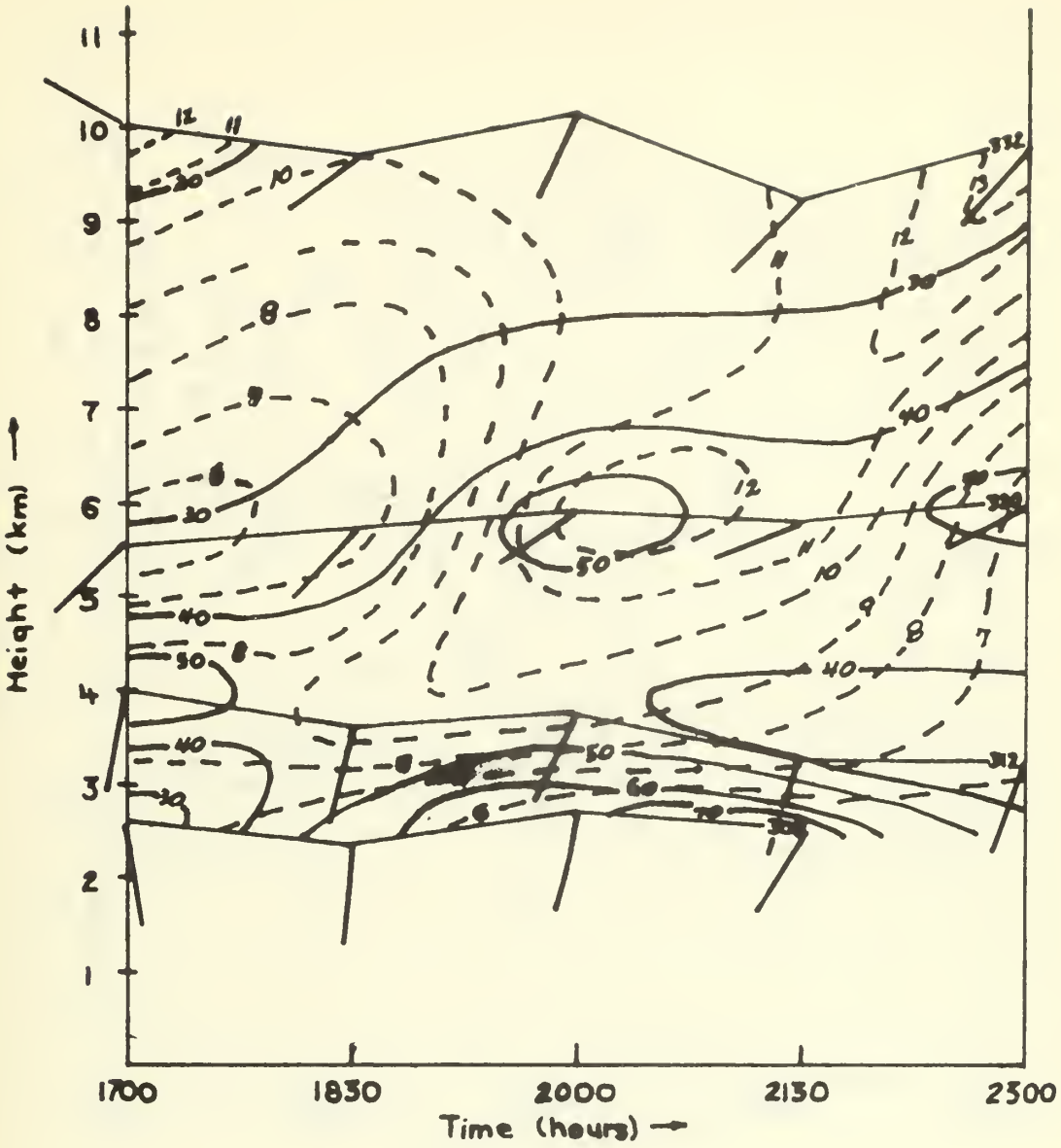


Figure 17b, Time section at station FSI, For explanation see fig, 17a,

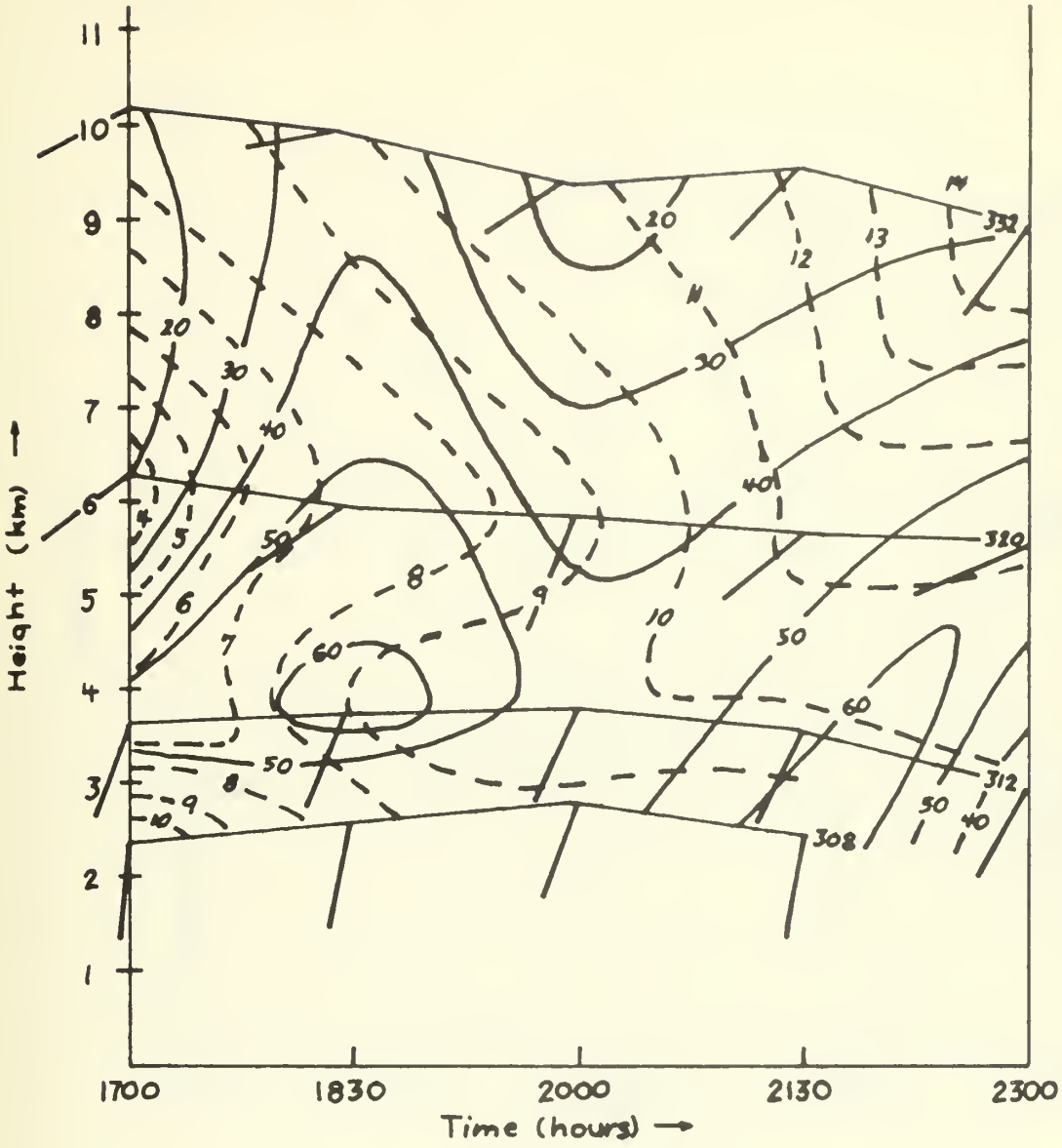


Figure 17c, Time section at station CHK, For explanation see fig, 17a,

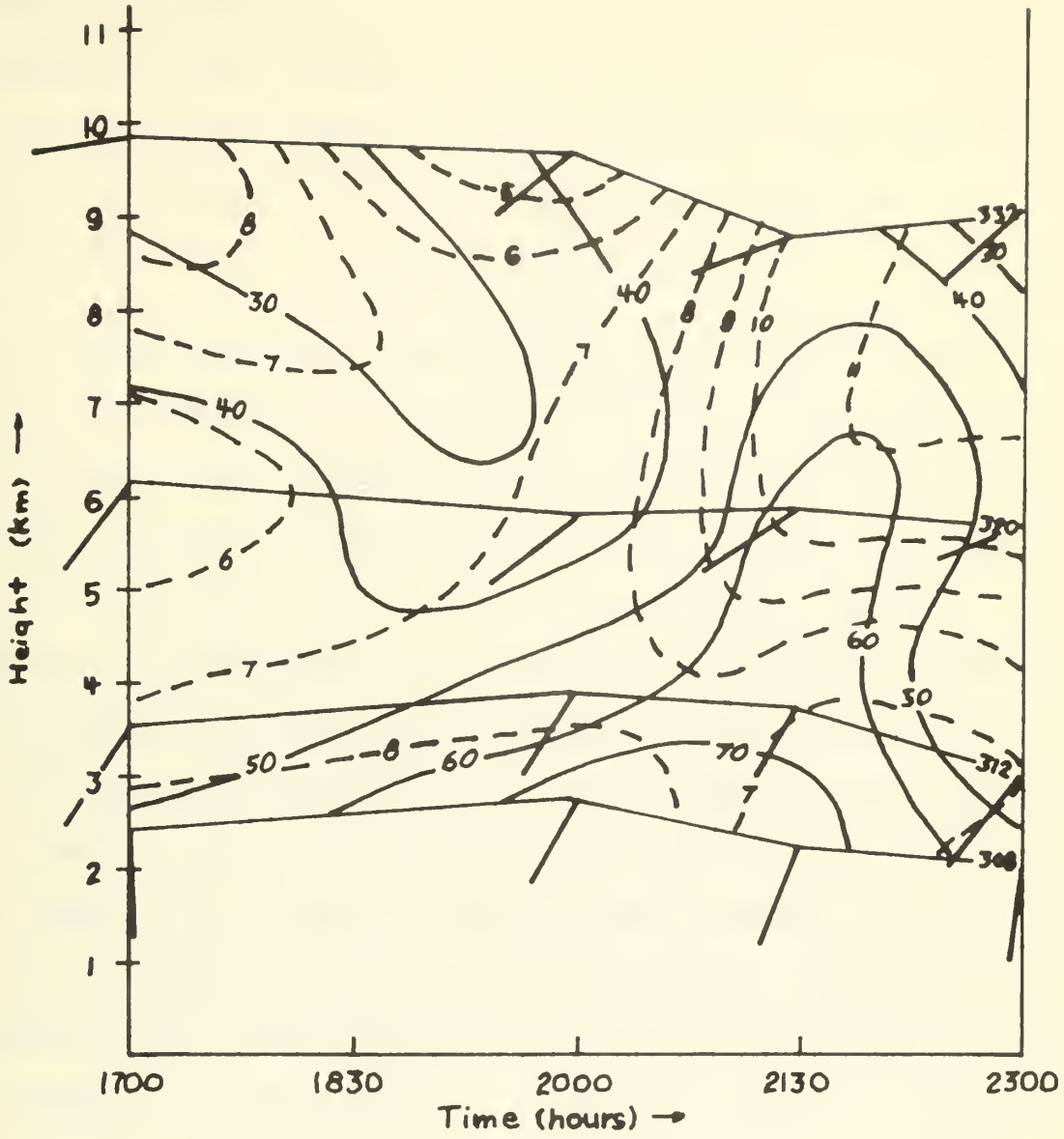


Figure 17d, Time section at station TIK, For explanation see fig, 17a,

the 332K theta surface. This wind shift could be further evidence of the passage of a wave through the area around 1700 GMT.

The relationship between the horizontal curvature of the trajectory (K_H) and the streamline (K_s) can be related by Blaton's equation:

$$K_H = K_s + \frac{1}{V_s} \frac{\partial ff}{\partial t} \tag{13}$$

where V_s is in the wind speed and $\frac{\partial ff}{\partial t}$ is the local rate of turning of the horizontal wind direction. At station FSI (Fig. 17b) $\frac{\partial ff}{\partial t}$ is positive, thus K_H should be greater than K_s, which is what is observed (Fig. 18). At station CHK (Fig. 17c) $\frac{\partial ff}{\partial t}$ is negative, thus K_H should be less than K_s, which is also the case (Fig. 18). If the streamlines are wave-shaped and if the wave moves with a speed greater than the mean wind speed, the curvature of the streamlines and trajectories may be of opposite sign and the trajectories will have a curvature greater than the streamlines. This approach implies that a wave having a phase speed greater than the mean wind speed is indeed present in the region.

The 1700-1830 GMT vertical motion, 1700 GMT static stability and divergence patterns were superimposed upon the 1700 GMT streamline flow on the 332K theta surface (Fig. 18). A parcel of air, with respect to a wave that is traveling faster than the mean wind speed, is actually moving toward the west. Thus the air parcels are experiencing convergence, sinking motions and entering a stability minimum area in the western portion of the grid.

From the conservation of potential vorticity on an isentropic surface, which is given by:

$$\frac{d}{dt} (\zeta_\theta \sigma) = 0 \tag{14}$$

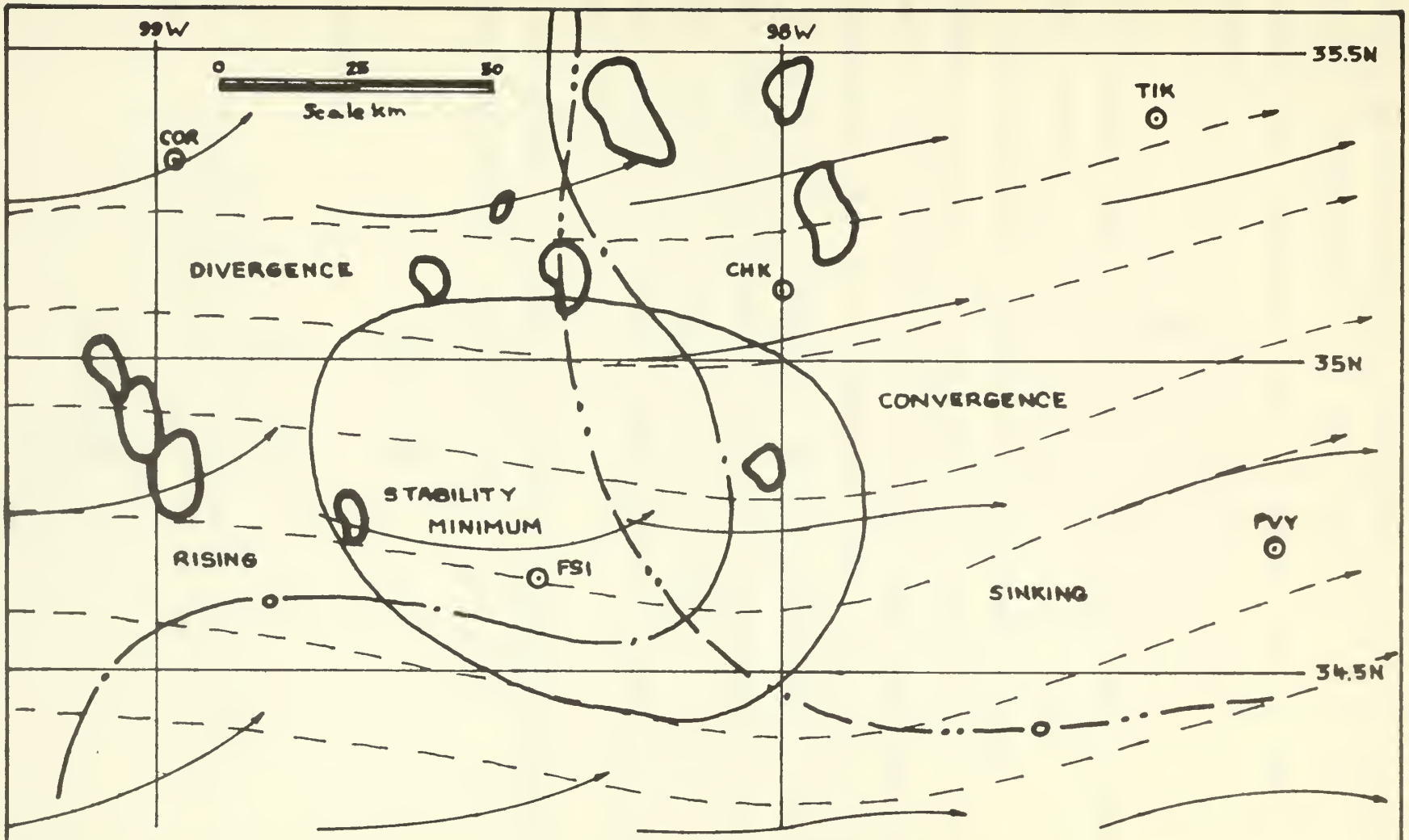


Figure 18, 332K. Theta surface, 1700 GMT streamlines (---), static stability (——) and divergence (—·—), 1700-1830 GMT vertical motion (——··——), 1830 GMT storm position, 1700-1830 GMT trajectories,

where ζ_θ and σ are defined as in equations (3) and (7), an air parcel entering a trough region would normally experience an increase in vorticity, thus requiring a decrease in static stability. From the continuity equation in isentropic coordinates in the form:

$$\frac{d\sigma}{dt} - \sigma\nabla_\theta \cdot V = 0 \tag{15}$$

it is seen that, where σ is positive, a parcel experiencing convergence must have a decrease in static stability.

There thus appears good evidence of the presence of a wave phenomenon in the region in the early stages of storm activity. There also is a good indication that the wave has a phase speed greater than the mean wind speed. The 1700 GMT model on the 332K isentropic surface gives evidence that the parameters can only be consistent for a wave speed greater than the mean wind speed. With this dynamically consistent model there has been established a region conducive to convective activity for the 1700-1830 GMT period which could initiate the severe storm activity.

For adiabatic, frictionless flow along a streamline, the equation of motion in isentropic coordinates reduces to the form:

$$\frac{dV_s}{dt} = -\frac{\partial M}{\partial S} \tag{16}$$

By assuming:

$$\frac{\partial}{\partial t} = -C\frac{\partial}{\partial s} \tag{17}$$

where C is the phase speed, equations 16 and 17 can be reduced to the form:

$$C = V_s + \frac{\frac{\partial M}{\partial S}}{\frac{\partial V_s}{\partial S}} \tag{18}$$

where V_s is the mean wind speed. Now by assuming a phase speed of twice the mean wind speed, a relationship for adjusting the mass field to the wind field can be obtained in the form:

$$\frac{\partial M}{\partial S} = V_s \frac{\partial V_s}{\partial S} \tag{19}$$

such that $\Delta M = \Delta V_s$ along the streamline for the same Δs. Figure 19 illustrates the adjustment that is necessary in the Montgomery stream function field. This adjusted field is dynamically consistent with the model that has been established on the 332K theta surface at 1700 GMT. Air parcels, moving with respect to the wave, which are experiencing an acceleration are also experiencing a decrease in Montgomery stream function. Thus knowledge of the wave in the region can be helpful in adjusting the mass and wind fields such that they are dynamically consistent.

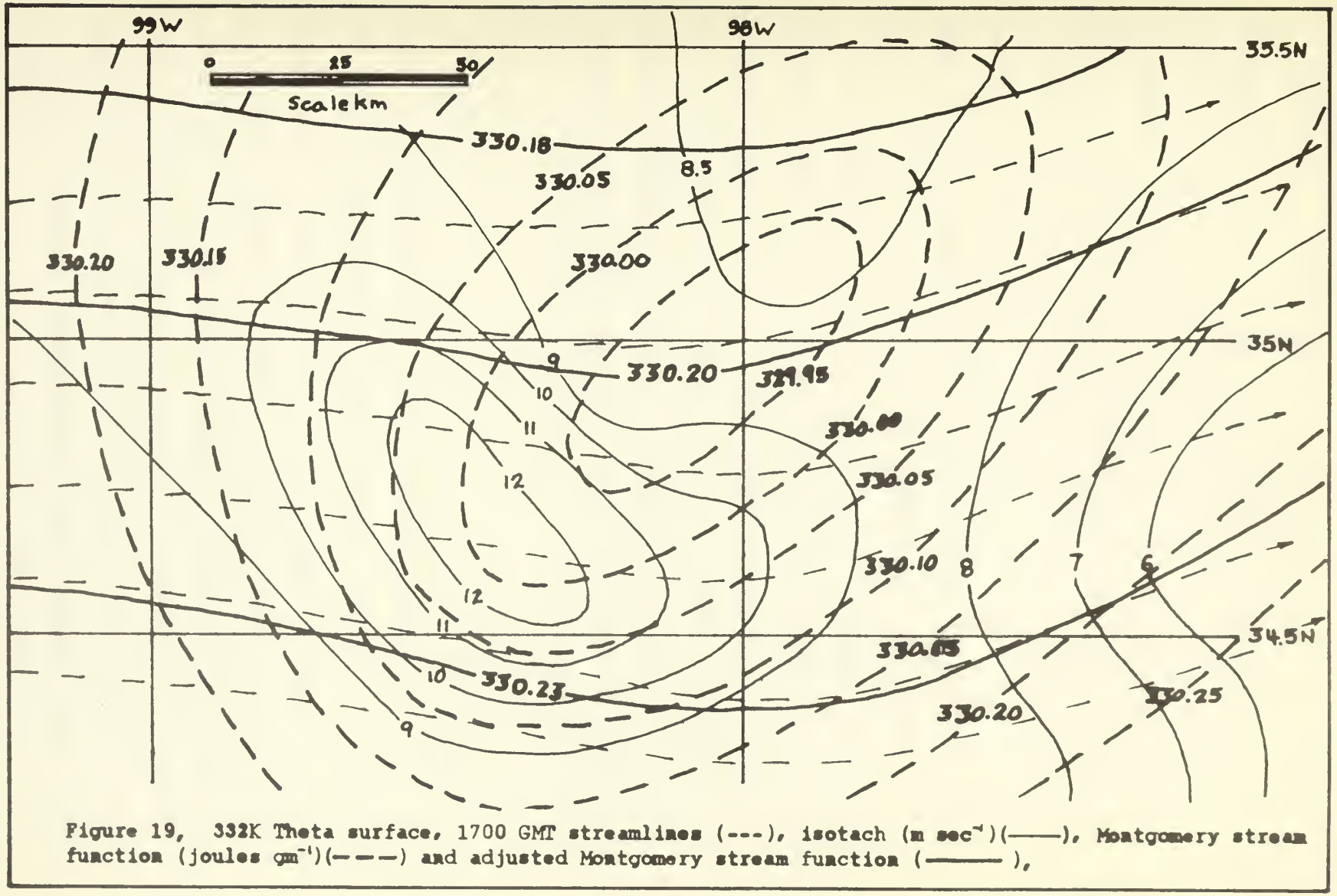


Figure 19, 332K Theta surface, 1700 GMT streamlines (---), isotach (m sec^{-1})(——), Montgomery stream function (joules gm^{-1})(— — —) and adjusted Montgomery stream function (————),

5. PROBLEMS ENCOUNTERED

One of the most demanding and important parts of the research are the initial analyzed fields. The problem has required the analysis of 100 data fields. Proper analysis involves both spatial and time considerations, as well as dynamical and thermodynamical relationships between variables. The horizontal gradients are very important as interpolations are made between network stations. Subjective smoothing can destroy the very detail that may well be important, but at the same time under smoothing may produce anomalies that invalidate subsequent studies. Station bias must be carefully considered.

On the synoptic scale, the normal concern of changes in a certain parameter that must be detected over a specified distance or time will usually be expressed in, say, whole numbers. However, for mesoscale work one must detect changes that amount to tenths or hundredths for a specified distance or time. The instrumentation for data collecting is the same for both scales of motion, thus the sensitivity of the instruments and the magnitude of instrument error and measurements is very critical.

Engelmann and Davis (1968) have found that the standard observational error in radiosonde data will give a computational error of 0.04×10^7 cm^2 sec^{-2} in the Montgomery stream function. These errors result from errors in the instruments and receiving equipment, baseline check and in the mean temperature. The M fields were analyzed for each 0.05×10^7 cm^2 sec^{-2} interval, which is about the value of the computational error. Thus the M values and analyses fields contain inaccuracies which effect calculations using these fields. It was seen in section 4D that the Montgomery stream function fields required rather large adjustments in order to be dynamically consistent with the winds.

Figures 20a-20e indicate the changes in the analyses for the 320K isentropic surface at time 2000 GMT when balloon displacement, location of the storm at analysis time, and a conscientious effort toward spatial and time continuity were made. The 320K surface was selected as a comparison for the re-analysis since its height fluctuations were minimal over the entire grid and between each data time. Isolines of Montgomery stream function were oriented along streamlines and rapid changes perpendicular to the flow were minimized. Pressure isolines were also oriented along the flow, as were relative humidity values. Also larger values of relative humidity were analyzed for, in the vicinity of the storm. Wind direction and speed considerations were carefully matched, particularly with respect to time continuity.

The effects of the re-analyses on the trajectories and values of the associated parameters were investigated to determine if any significant changes resulted. Figure 21 shows the comparison between the initial analysis (IA) and the re-analysis (RA) for selected trajectories and their associated parameters. Vertical motion (VM) (mb hr^{-1}), acceleration (A) (m sec^{-1}), vorticity change (V CHG) (sec^{-1}), divergence change (D CHG) (sec^{-1}), total energy change (TE CHG) (10^{7} erg gm^{-1}), static stability change (SS CHG) (^{o}K mb^{-1}) and potential vorticity change (PV CHG) (10^{-10} ^{o}K sec cm gm^{-1}) are given for each of the trajectories. Vertical motions and accelerations are smaller for the re-analyzed case and there are two cases which have sign changes. The re-analyzed trajectories have more cyclonic curvature in the vicinity of the storm, and trajectory 1 has more anticyclonic curvature. Other parameters show little difference.

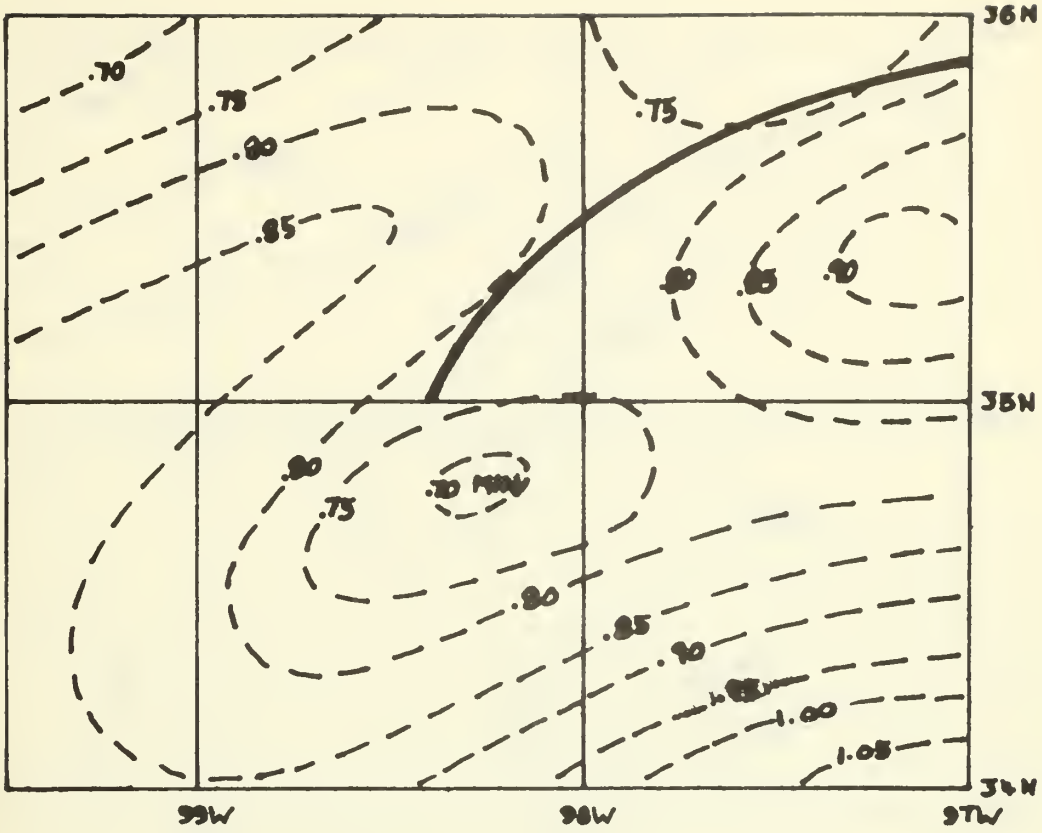


Figure 20a, 320K Theta surface, 2000 GMT Montgomery stream function re-analysis, See fig, 2a for explination,

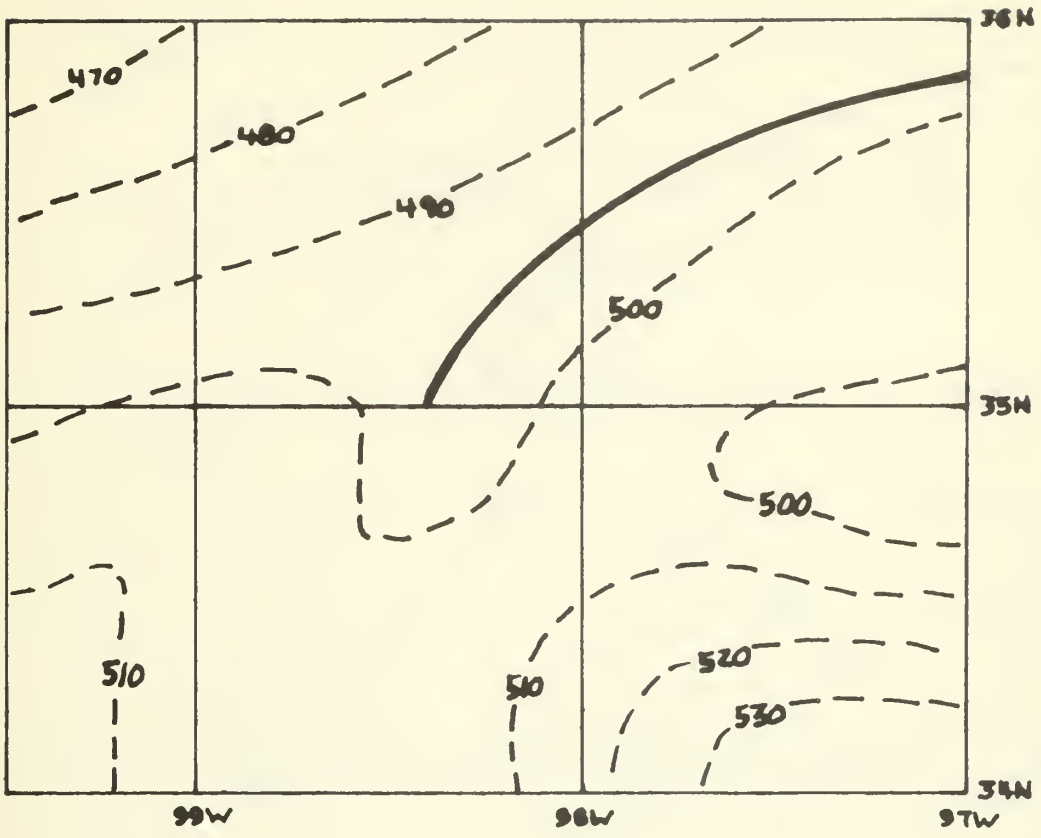


Figure 20b, 320K Theta surface, 2000 GMT pressure (mb) re-analysis,

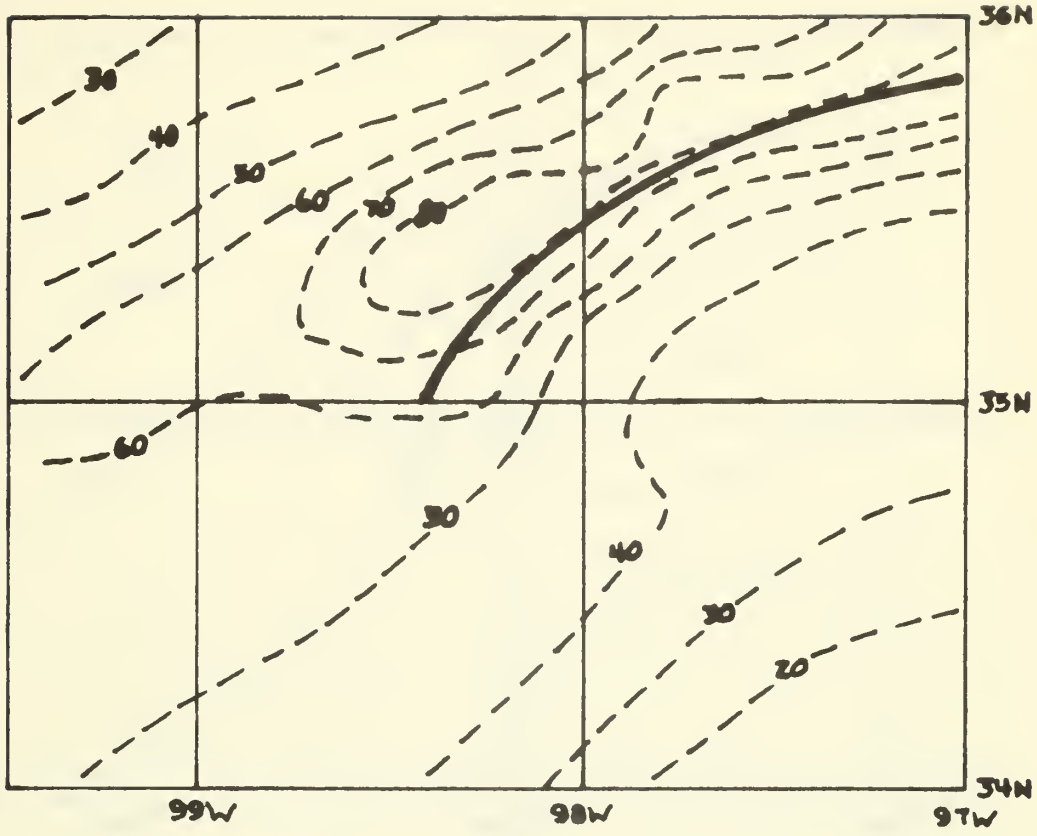


Figure 20c, 320K Theta surface, 2000 GMT relative humidity (%) re-analysis,

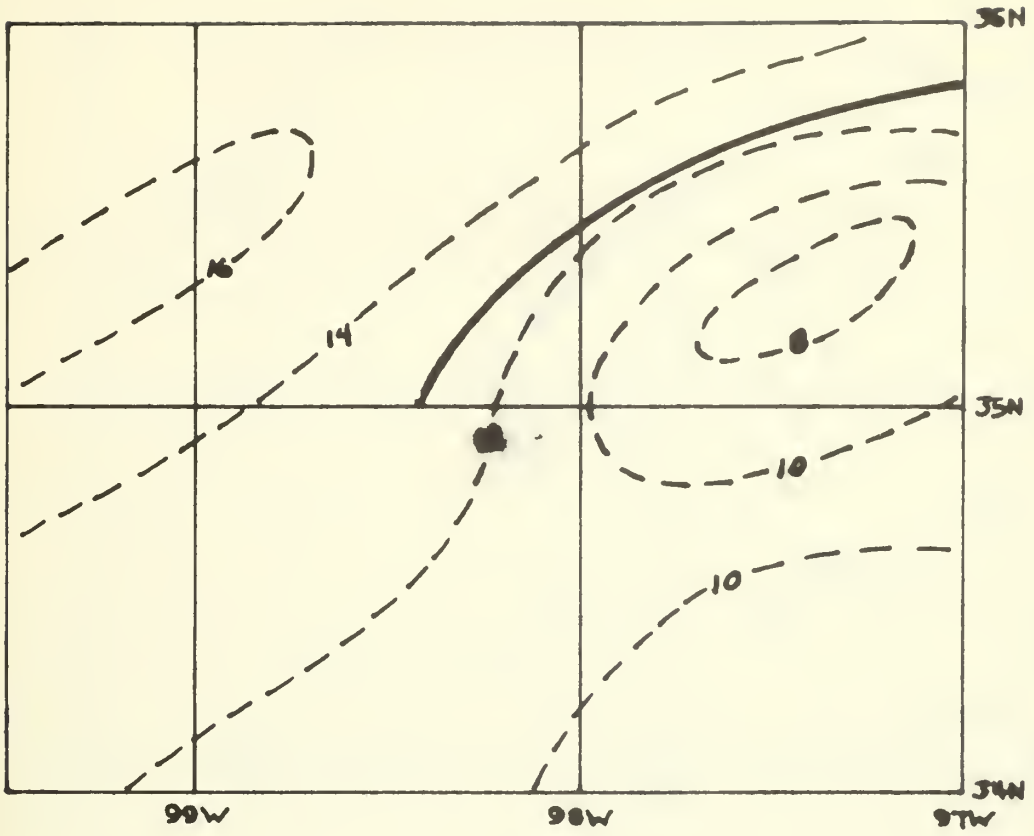


Figure 20d, 320K Theta surface, 2000 GMT wind speed (m sec^{-1}) re-analysis,

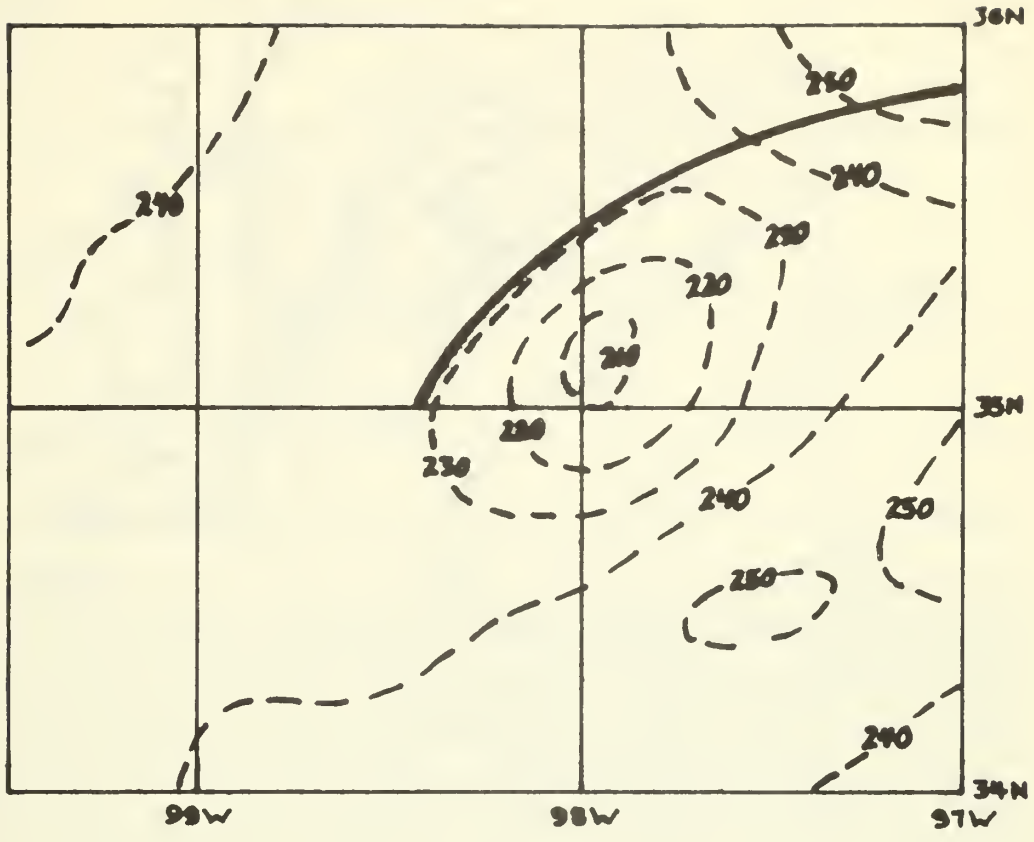
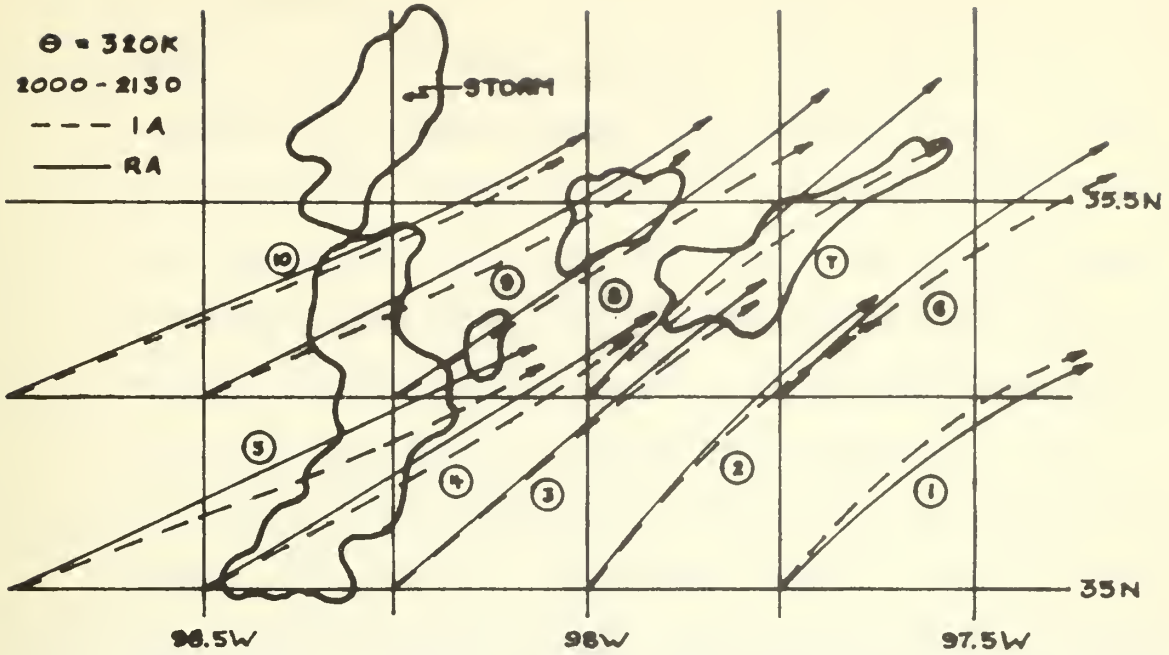


Figure 20a, 320K Theta surface, 2000K wind direction (degs from north) re-analysis,



TRAJ		VI	A	V CHG	D CHG	TE CHG	SS CHG	PV CHG
1	IA	2.0	1.2	- 0.23	0.19	0.74	.001	- 11.4
	RA	1.4	1.3	- 0.58	- 0.34	0.55	0.0	- 30.4
2	IA	2.0	1.2	- 0.88	0.55	0.81	-..001	- 46.4
	RA	- 0.1	0.9	- 0.43	0.73	0.87	- .002	- 23.5
3	IA	4.9	0.2	- 0.71	1.46	0.58	- .001	- 35.0
	RA	2.5	- 0.3	- 0.21	1.32	0.48	- .001	- 11.1
4	IA	7.1	- 0.7	- 0.45	0.79	0.17	.002	- 18.7
	RA	2.5	- 0.6	- 0.01	0.37	0.44	0.0	- 0.1
5	IA	6.7	- 1.2	0.51	- 0.23	- 0.23	.003	24.6
	RA	2.2	- 0.9	0.58	- 0.33	0.42	.002	29.4
6	IA	- 5.3	1.8	1.21	0.10	0.95	- .006	60.8
	RA	- 4.5	2.3	0.76	0.17	1.27	- .003	40.2
7	IA	- 5.4	1.2	0.63	1.12	0.95	- .008	28.4
	RA	- 3.1	0.9	0.14	1.83	1.15	- .003	7.9
8	IA	0.6	0.0	- 0.08	1.61	0.86	- .004	- 5.0
	RA	- 0.1	- 0.1	- 0.58	1.48	0.41	- .001	- 27.7
9	IA	4.8	- 1.0	0.02	0.12	0.58	- .001	0.4
	RA	1.7	- 0.6	0.22	0.02	0.10	.002	10.9
10	IA	5.9	- 1.5	0.14	- 0.39	0.15	.001	5.9
	RA	2.6	- 0.9	0.95	- 0.50	0.87	.003	44.5

Figure 21, Initial and re-analysis comparison,

Using equation 16 and the 2000-2130 GMT accelerations that were computed from the kinematic isentropic trajectories, the expected changes in the Montgomery stream function values along a selected ΔS of 50 KM were computed at various areas over the grid on the 320K theta surface (Fig. 22). The solid black lines are the analyzed M field based on the data at the nine NSSL upper air stations at 2000 GMT. The values are given in units of 10^7 cm^2 sec^{-2}. The dashed black lines represent the 2000-2130 GMT accelerations (m sec^{-1} hr^{-1}) and the short green lines are the position of ΔS over the area. In Table 1 a comparison of the predicted value and measured value for the M values are given. In many cases there is almost an order of magnitude difference, with the predicted values having a much lower absolute value. Using these predicted changes and approximate values at each station, an adjustment to the M field was made (Fig. 22 - red dashed lines). This new M field is now dynamically consistent with the winds. It would thus seem that the Montgomery stream function and hence the temperature and height fields are in error. It is not conclusive however, but along with the adjustments in the M field discussed in Section 4D there appears to be unacceptable errors in the initial data fields of Montgomery stream function. From this point of view, therefore it appears the wind data is more accurate.

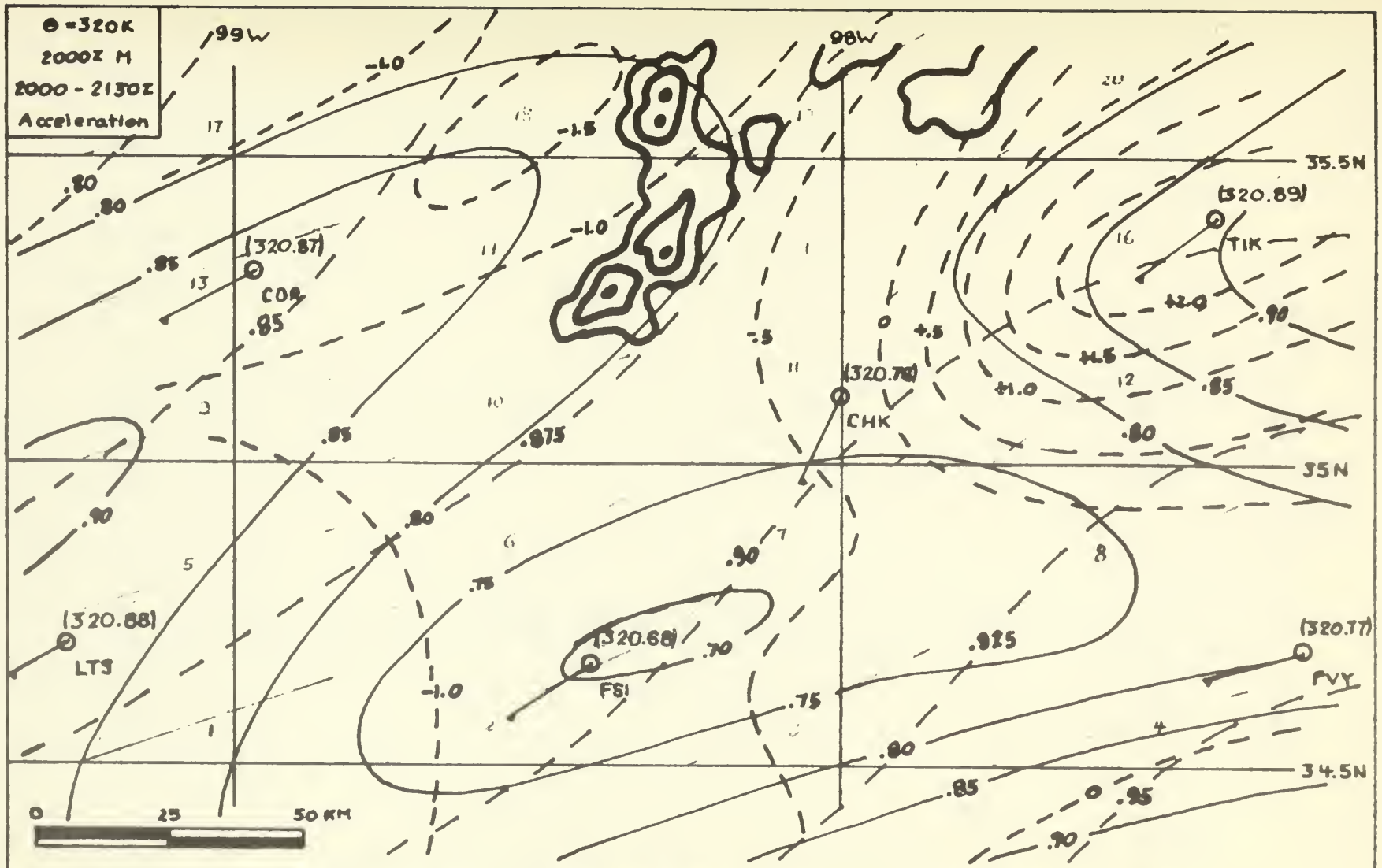


Figure 22, 320K Theta surface, 2000 GMT Montgomery stream function adjustment,

TABLE 1

Predicted and Measured M Value Comparison

Calculation Point	Acceleration ($m\ sec^{-1}\ hr^{-1}$)	M Predicted ($cm^2\ sec^{-2}$)	M Measured ($cm^2\ sec^{-2}$)
1	-1.4	+.020	-.08
2	-0.9	+.013	-.07
3	-0.5	+.007	0.03
4	-0.1	+.001	0.01
5	-1.3	+.018	0.05
6	-0.9	+.013	-.01
7	-0.6	+.008	+.06
8	-0.2	+.003	+.05
9	-1.0	+.014	-.05
10	-0.8	+.011	-.03
11	-0.4	+.006	+.03
12	+1.1	-.016	+.14
13	-1.2	+.017	+.01
14	-1.0	+.014	-.04
15	-0.4	+.006	-.01
16	+2.0	-.028	+.05
17	-0.9	+.013	+.01
18	-1.5	+.021	-.04
19	-0.7	+.010	-.03
20	+1.0	-.014	0.0

6. COMPARISON WITH THEORY

In the basic assumption of frictionless, adiabatic flow along an isentropic surface, on which the study was based, there are three parameters which should be conserved for an air parcel moving in the flow. These parameters are potential temperature (θ) (^{o}K), specific humidity (q) (gm gm^{-1}) and potential vorticity (P) (10^{-10} ^{o}K sec cm gm^{-1}). The initial input fields into the computer program were analyzed on constant theta surfaces, thus the program constrained theta to be conserved for each trajectory. However, specific humidity and potential vorticity were allowed to vary.

Selected composite trajectories were studied in order to determine both short (1.5 hour) and long (6 hour) term variations. In Figure 22 and Table 2 the deviations are shown for the 320K theta surface. Vertical motions (ω) (mb hr^{-1}), accelerations (A) (m sec^{-1} hr^{-1}), static stability (σ) (^{o}K mb^{-1}) and total energy (TE) (10^{7} erg gm^{-1}) were also studied in conjunction with the conserved properties to determine if any correlations exist. Trajectories labeled 1A-1F are for 1700-1830 GMT; 2A-2F for 1830-2000 GMT; 3A-3F for 2000-2130 GMT; and 4A-4F for 2130-2300 GMT. Both initial (i) and final (f) values for each of the properties are given.

With the exception of 1A-1F trajectories, the specific humidity was somewhat conserved for each trajectory. Changes are random and do not appear to be associated with vertical motions or accelerations. Trajectories 2E and 3F indicate their deviations may be from the storm effects, since their initial point is outside the storm and final point inside the storm region.

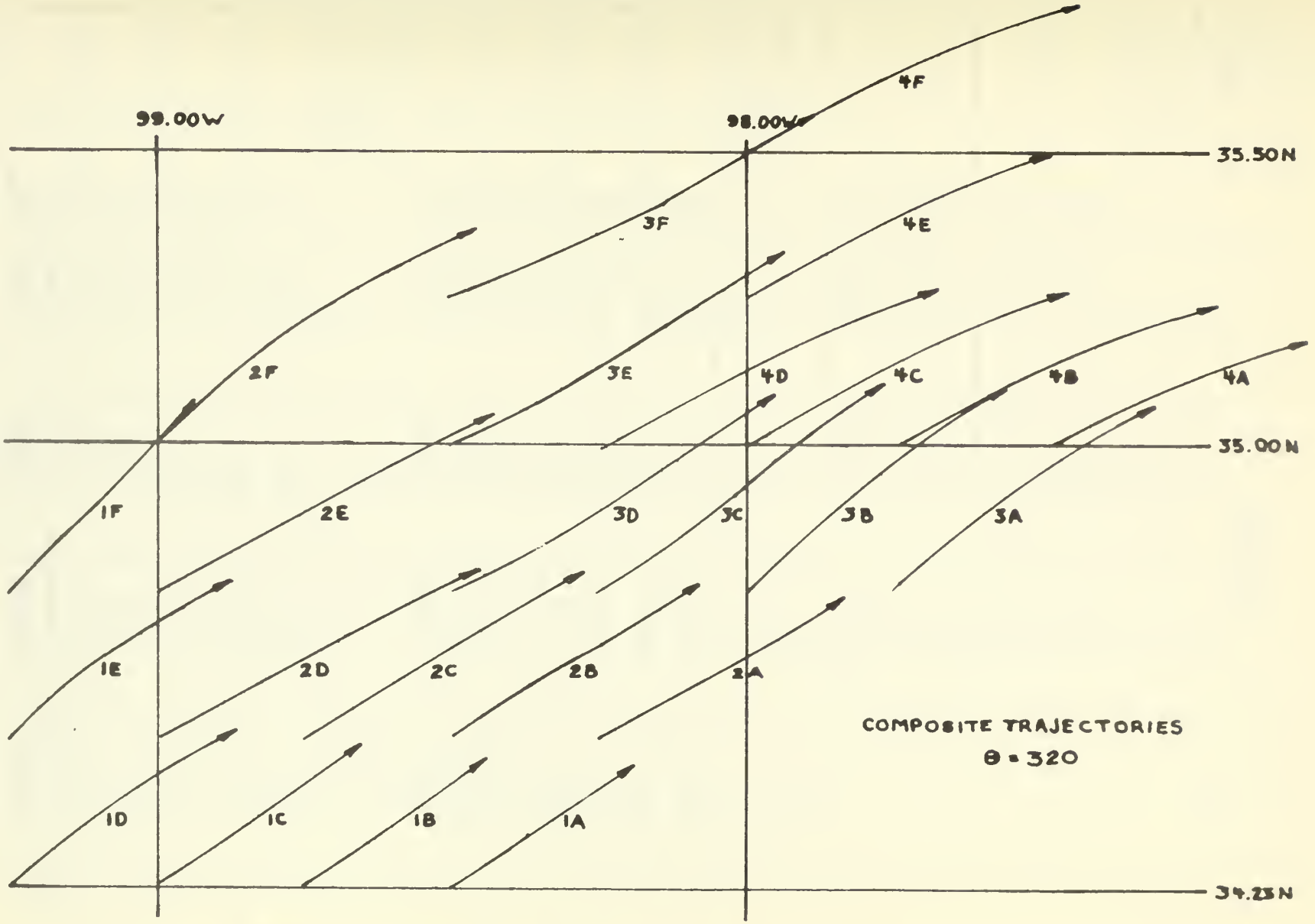


Figure 23, 320K Theta surface composite trajectories,

THETA = 320		TRAJECTORY			
		1A	2A	3A	4A
ω		-7,5	-1,1	+7,4	
A		-0,3	+3,2	-0,9	
q	i	,0007	,0012	,0012	
	f	,0011	,0012	,0014	
σ	i	,051	,051	,050	
	f	,051	,051	,055	
p	i	60,56	48,51	94,05	
	f	49,62	106,34	29,63	
TE	i	321,64	322,12	322,11	
	f	322,09	322,15	322,40	
		1B	2B	3B	4B
ω		-6,7	-3,8	+5,6	+5,3
A		-0,2	+3,1	-0,7	-0,1
q	i	,0005	,0013	,0013	,0015
	f	,0013	,0015	,0016	,0019
σ	i	,051	,052	,052	,053
	f	,052	,052	,055	,042
p	i	51,49	27,33	134,37	25,09
	f	33,58	116,73	26,67	25,25
TE	i	321,51	322,27	322,25	322,48
	f	322,25	322,39	322,56	323,06
		1C	2C	3C	4C
ω		-6,1	-8,3	+8,7	-1,1
A		+0,3	+2,2	-0,6	-0,8
q	i	,0004	,0014	,0018	,0017
	f	,0013	,0018	,0017	,0018
σ	i	,049	,052	,051	,051
	f	,052	,051	,052	,038
p	i	28,19	16,97	92,65	38,11
	f	21,01	81,67	25,83	45,73
TE	i	321,37	322,35	322,77	322,66
	f	322,32	322,71	322,65	322,79

Table 2

		TABLE 2 (Continued)			
		1D	2D	3D	4D
ω		-6,7	-9,5	+9,3	-5,5
A		+1,1	+1,3	-0,8	-1,8
q	i	,0002	,0013	,0017	,0016
	f	,0013	,0017	,0017	,0018
σ	i	,048	,052	,049	,049
	f	,052	,048	,050	,035
p	i	33,81	28,46	37,53	84,93
	f	23,14	48,51	34,34	45,99
TE	i	321,18	322,33	322,70	322,58
	f	322,34	322,70	322,69	322,71
		1E	2E	3E	4E
ω		-5,4	-14,7	+7,1	+3,1
A		+1,7	+1,1	-0,7	-2,5
q	i	,0003	,0013	,0017	,0018
	f	,0042	,0016	,0018	,0019
σ	i	,050	,053	,044	,047
	f	,053	,045	,046	,036
p	i	19,39	40,21	45,17	34,47
	f	34,25	41,42	26,46	40,29
TE	i	321,26	322,34	322,72	322,77
	f	322,36	322,60	322,89	322,98
		1F	2F	3F	4F
ω		-3,0	-20,7	+4,8	+10,1
A		+2,4	+1,9	-1,0	-1,5
q	i	,0004	,0013	,0016	,0020
	f	,0013	,0014	,0021	,0019
σ	i	,050	,056	,041	,040
	f	,057	,041	,040	,035
p	i	19,84	62,96	16,73	18,60
	f	25,51	15,33	17,18	27,46
TE	i	321,42	322,36	322,59	323,03
	f	322,37	322,45	323,17	322,98

7. CONCLUSIONS

The research has demonstrated the critical nature of mesoscale data both in instrumentation and analysis errors. It was found that the wind data were perhaps the most reliable for use in the study. Subsequently the 1.5 hour kinematic isentropic trajectory relationship to the severe local storm warranted considerable exploration. It was further noted that the 320K theta surface (approximately 500 mb) showed the trajectory and air parcel properties which were more closely associated with the life cycle of the storm.

The trajectories indicated that prior to storm development the wind veered with height at all levels, flow was anticyclonic with the exception of cyclonic flow in the NW corner in upper levels, and a wind maximum region existed in the NW corner of the network. With the presence of an inertial-gravity wave at the 332K theta surface at 1700 GMT, the dynamically consistent vertical motions, static stability, convergence, trajectories, streamlines and adjusted Montgomery stream function fields support conditions which could initiate convective activity. It was also noted that the storm is to the NE of the Wichita mountains, and the existance of a lee wave supporting the inertial-gravity wave is worthy of additional studies.

The study of various air parcel properties on the isentropic surfaces has provided insights into the storm dynamics. The 1830-2000 GMT vertical motions indicated supporting rising motions for storm growth. The 2000-2130 GMT, 320K theta surface convergence patterns help to illustrate the intensity of the storm during this period. The lack of supporting vertical motions, and the anticyclonic flow in each level tended to provide the response necessary for decay of the storm over the 2130-2300 GMT period.

The orientation of the storm along the upper level trajectories in the early stages and along the low level trajectories in the latter stages may be indicative of storm movement. When the storm orientation is considered along with the inertial-gravity wave, there exists the possibility the storm formed at high levels and propagated downward into the lower levels. It is concluded that the kinematic isentropic trajectories, over short periods of time, do provide an effective method for studying local severe storm activity in the mesoscale range.

8. SUGGESTIONS FOR FUTURE DEVELOPMENTS AND IMPROVEMENTS

Since the initial data fields are critical to the success of the computer model, it would be of benefit to investigate the application of error analysis techniques in order to improve the initial data. Further studies are necessary when corrections for Montgomery stream function changes can be made, in order to improve the final trajectories. Incorporation of diabatic effects in regions where air parcels are becoming saturated prior to the final trajectory point can be included in the model. Further studies of different storm systems is encouraged in order to test the short period kinematic isentropic trajectories, and to determine if they can be utilized as a forecasting aid. Since there existed deviations in conservation of specific humidity and potential vorticity along the trajectories, additional research will be necessary to investigate the conservation of these properties. With the supporting evidence of an inertial-gravity wave in the region, a theoretical approach is recommended in order to study the phenomenon in the range of wave length and wave speed encountered in this case study.

BRADLEY, W. E. and P. J. FETERIS, 1966: Study of rainout of radioactivity in Illinois. Fifth Progress Report, AEC Contract No. AT (11-1)-1199.

BROWNING, K. A. and T. FUJITA, 1965: A family outbreak of severe local storms - a comprehensive study of the storms in Oklahoma on 26 May 1963, part I. AFCRL Report No. AFCRL-65-695(1), Special Report No. 32.

_____, and F. H. LUDLAM, 1962: Airflow in convective storms. Quarterly Journal of the Royal Meteorological Society, Vol. 88, 117-135.

BYERS, H. and R. BRAHAM, 1949: The Thunderstorm. U. S. Government Printing Office, Washington, D. C., 287 pp.

CARLSON, T. N. and F. H. LUDLAM, 1968: Conditions for the occurrence of severe local storms. Tellus, Vol. XX, pp 203-226.

DANIELSEN, E. F., 1959: The laminar structure of the atmosphere and its relation to the concept of a tropopause. Archiv fur Meteorologie, Geophysik und Bioklimatologie, All, 293-332.

_____, 1961: Trajectories: isobaric, isentropic and actual. Journal of Meteorology, Vol. 18.

DARKOW, G. L., 1968: The total energy environment of severe storms. Journal of Applied Meteorology, Vol. 7, pp 199-205.

ENDLICH, R. M. and R. L. MANCUSO, 1968: Objective analysis of environmental conditions associated with severe thunderstorms and tornadoes. Monthly Weather Review, Vol. 96, No. 6, pp 342-350.

ENGELMANN, R. J. and W. E. DAVIS, 1968: Low-level isentropic trajectories and the midas computer program for the Montgomery stream function. U. S. Atomic Energy Commission Contract AT (45-1)-1830.

FANKHAUSER, J. C., 1964: On the motion and predictability of convective systems. NSSP Report No. 21, U. S. Weather Bureau.

_____, 1968: Thunderstorm-environment interactions revealed by chaff trajectories in the mid-troposphere. NSSL Tech. Memo. No. 39, U. S. Weather Bureau.

FETERIS, P. J. and G. E. STOUT, 1966: Relation of lightning, rainfall, and hail to the properties of mesoscale meteorological patterns. First Progress Report, NSF Contract No. GP-5196.

HAMMOND, G. R., 1967: Study of a left moving thunderstorm of 23 April 1964. NSSL Tech. Memo. No. 31, U. S. Weather Bureau.

KREITZBERG, C. W. and W. E. BROCKMAN, 1966: Computer processing of mesoscale rawinsonde data from project stormy spring. AFCRL Special Report No. 41.

MAHLMAN, J. D., 1968: Numerical methods of computing three-dimensional trajectories for adiabatic and diabatic flows. AFCRL Report No. 68-0357.

MATSUMOTO, S., K. NINOMIYA and T. AKIYAMA, 1967: Cumulus activities in relation to the mesoscale convergence field. Journal of Meteorological Society of Japan, Vol. 45, No. 4, pp 292-304.

MILLER, R. C., 1967: Semi-objective evaluation of the relative importance of parameters favoring production of severe local storms. Fifth Conference on Severe Local Storms, 1967.

NAMIAS, J., 1940: Air Mass and Isentropic Analysis. The American Meteorological Society, Milton, Mass.

NEWTON, C. W. and J. C. FANKHAUSER, 1964: On the movements of convective storms, emphasis on size discrimination in relation to water-budget requirements. Journal of Applied Meteorology, Vol. 3, pp 651-668.

REITER, E. R. and E. F. DANIELSEN, 1960: Bemerkungen zu E. Kleinschmidt: Nicht-adiabatische Abkuhlung im Bereich des jet stream. Beitrage zur Physik der Atmosphare, 32, 265-273.

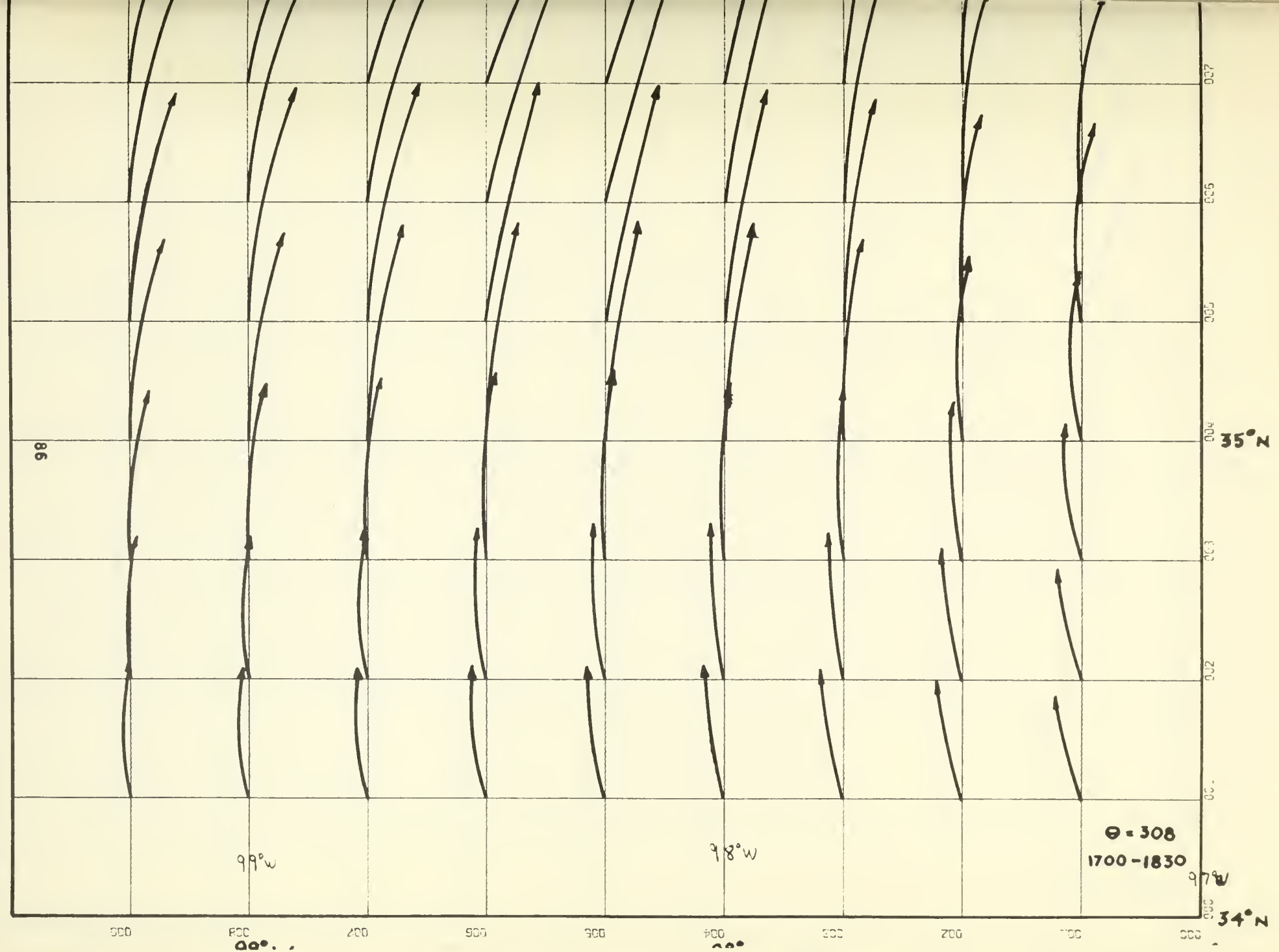
_____, 1963: A case study of radioactive fallout. Journal of Applied Meteorology, 2, 691-705.

ROSSBY, C. G. and Collaborators, 1937: Isentropic analysis. Bulletin of the American Meteorological Society, Vol. 18, pp 201-209.

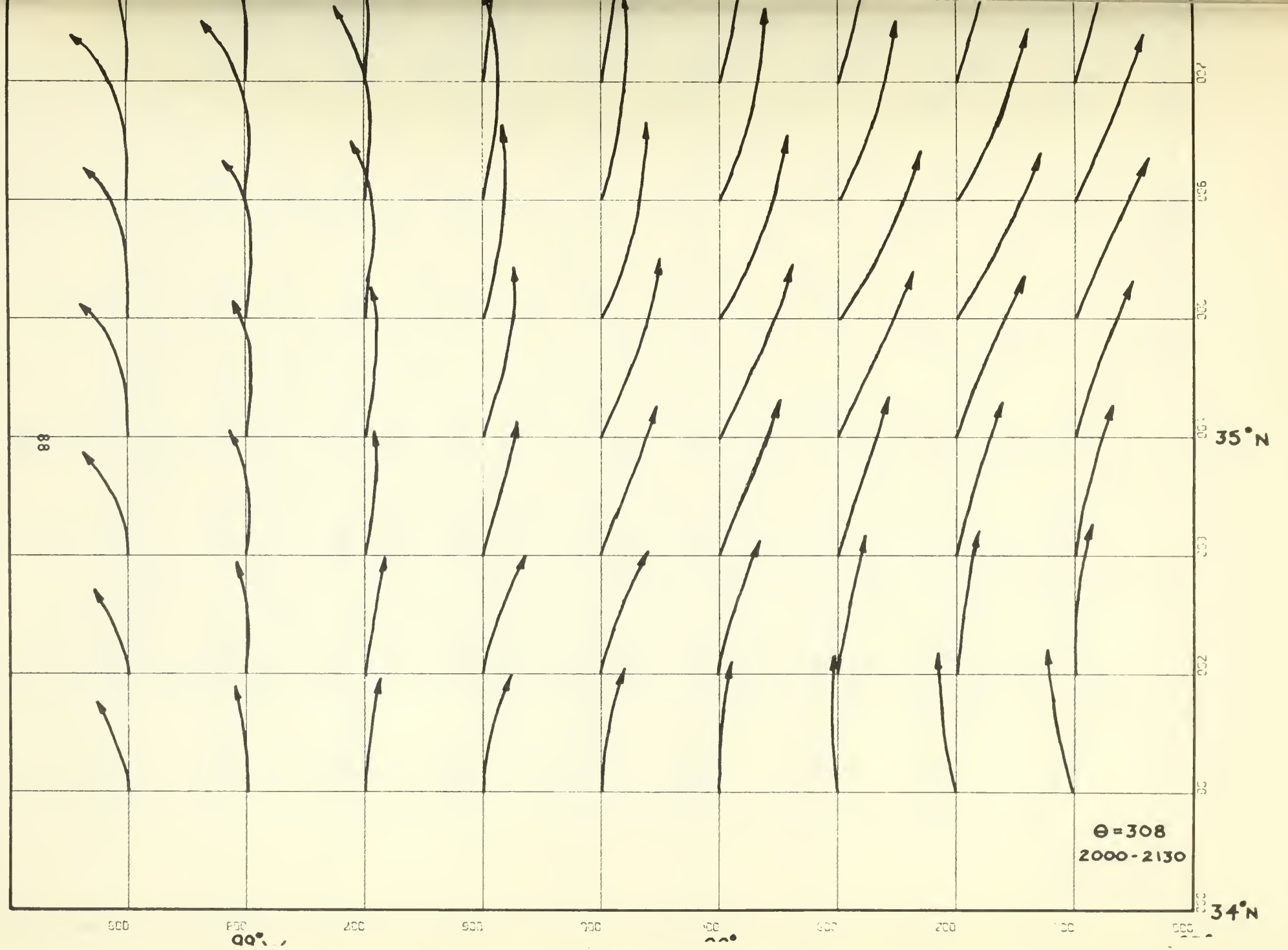
WILLIAMS, D. T., 1962: A study of the kinematic properties of certain small-scale systems. NSSP Report No. 11, U. S. Weather Bureau.

APPENDIX A - ISENTROPIC KINEMATIC TRAJECTORIES

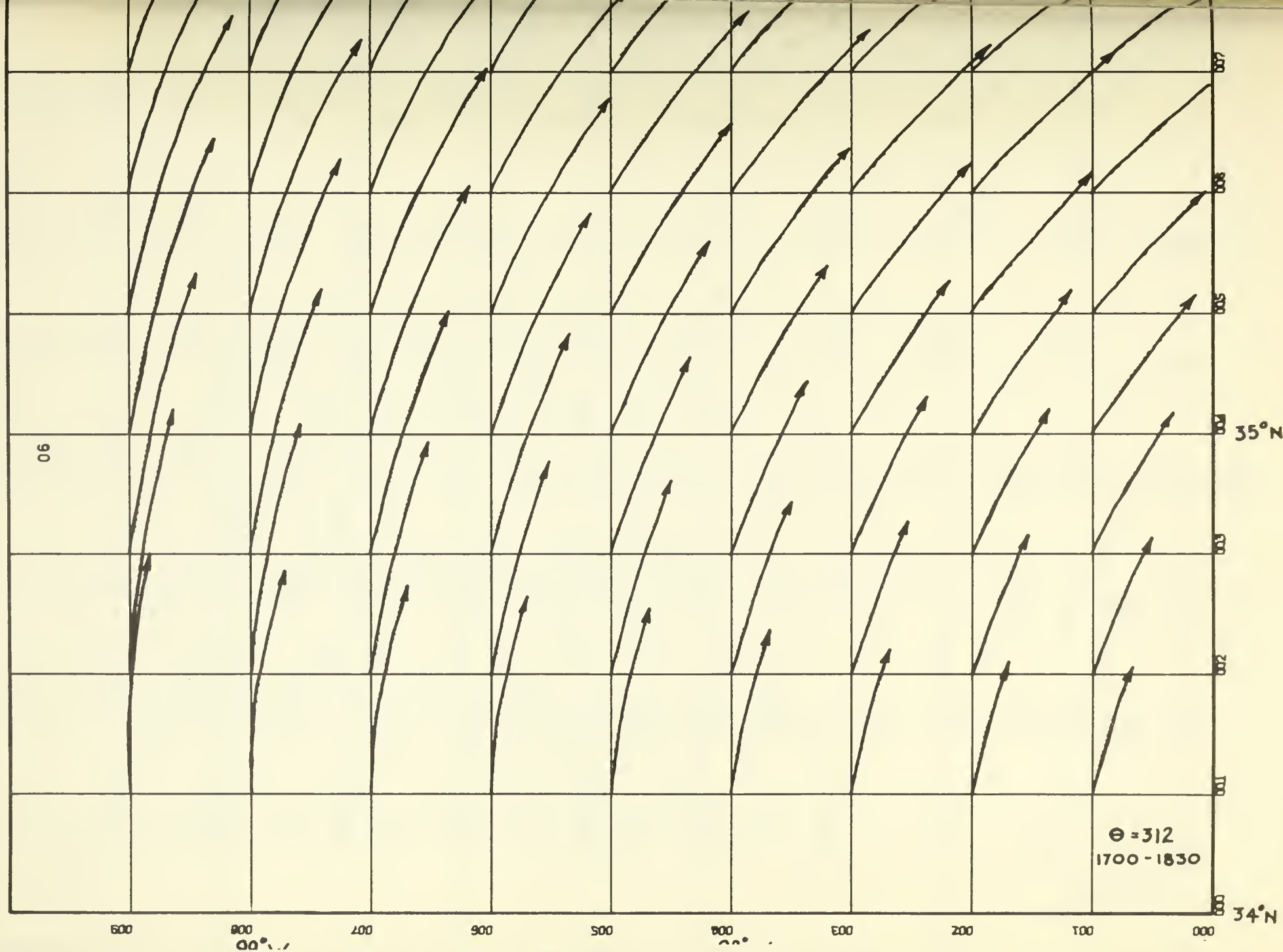
This appendix includes the kinematic trajectories which have been computed for the 308K, 312K, 320K and 332K isentropic surfaces for the time periods 1700-1830, 1830-2000, 2000-2130 and 2130-2300 GMT. They were produced by the objective computer model for the May 28, 1967 severe storm case. The grid is an x, y grid, with equal grid spacing.

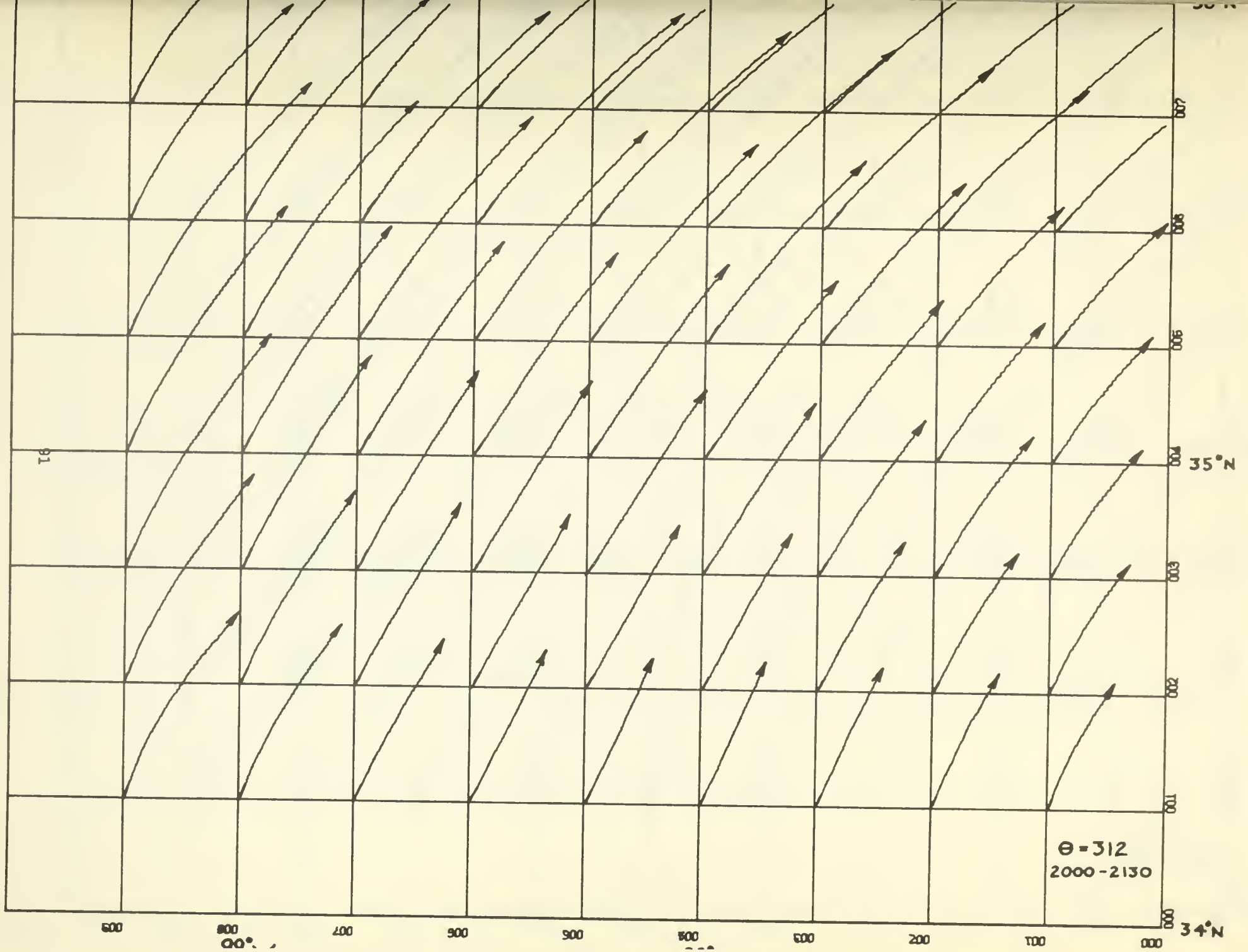

35°N
34°N
99°W
98°W
97°W
Θ = 308
1700 - 1830

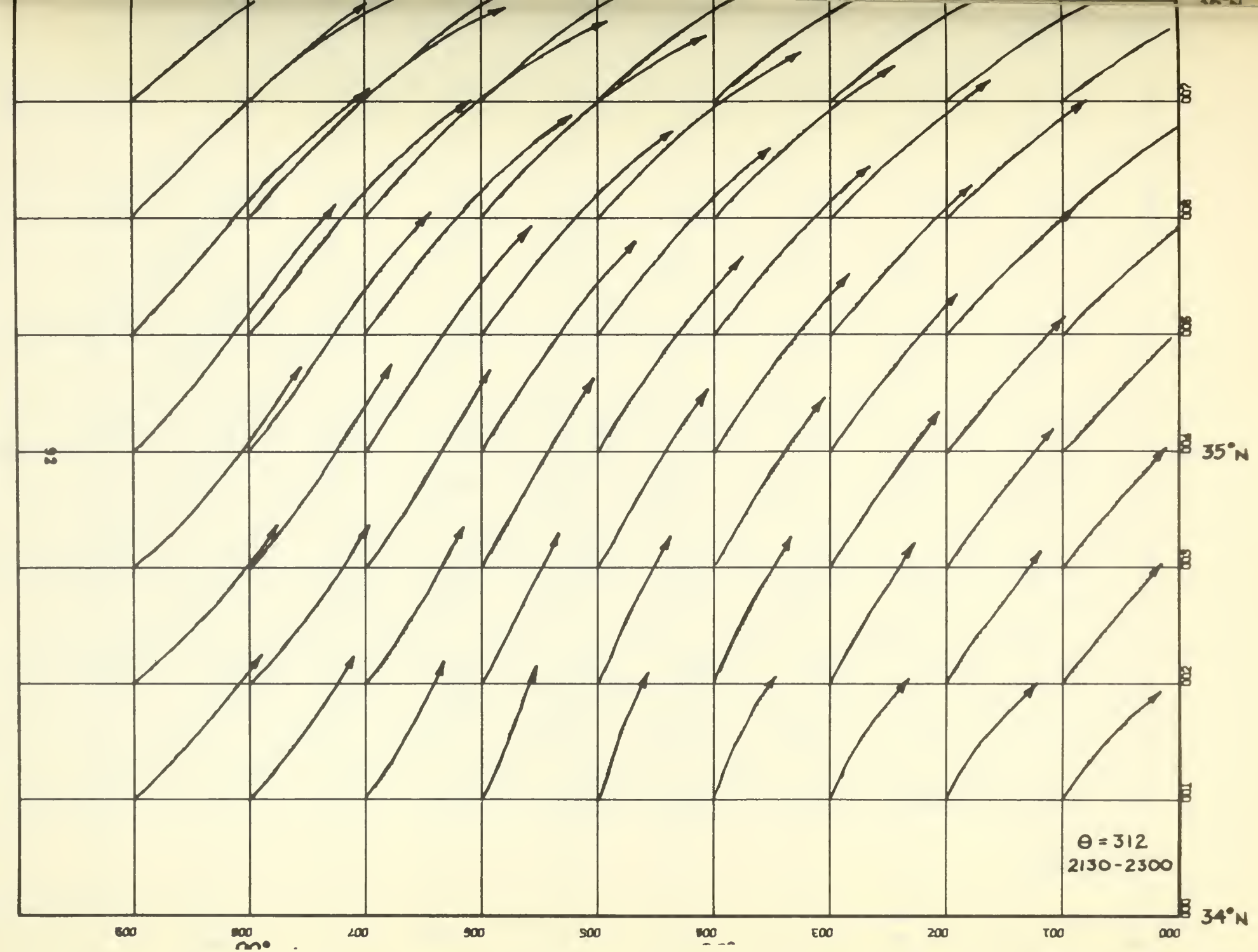
Θ=308
1830-2000
35° N
34° N
000
001
002
003
004
005
006
007
000
001
002
003
004
005
006
007
008
009

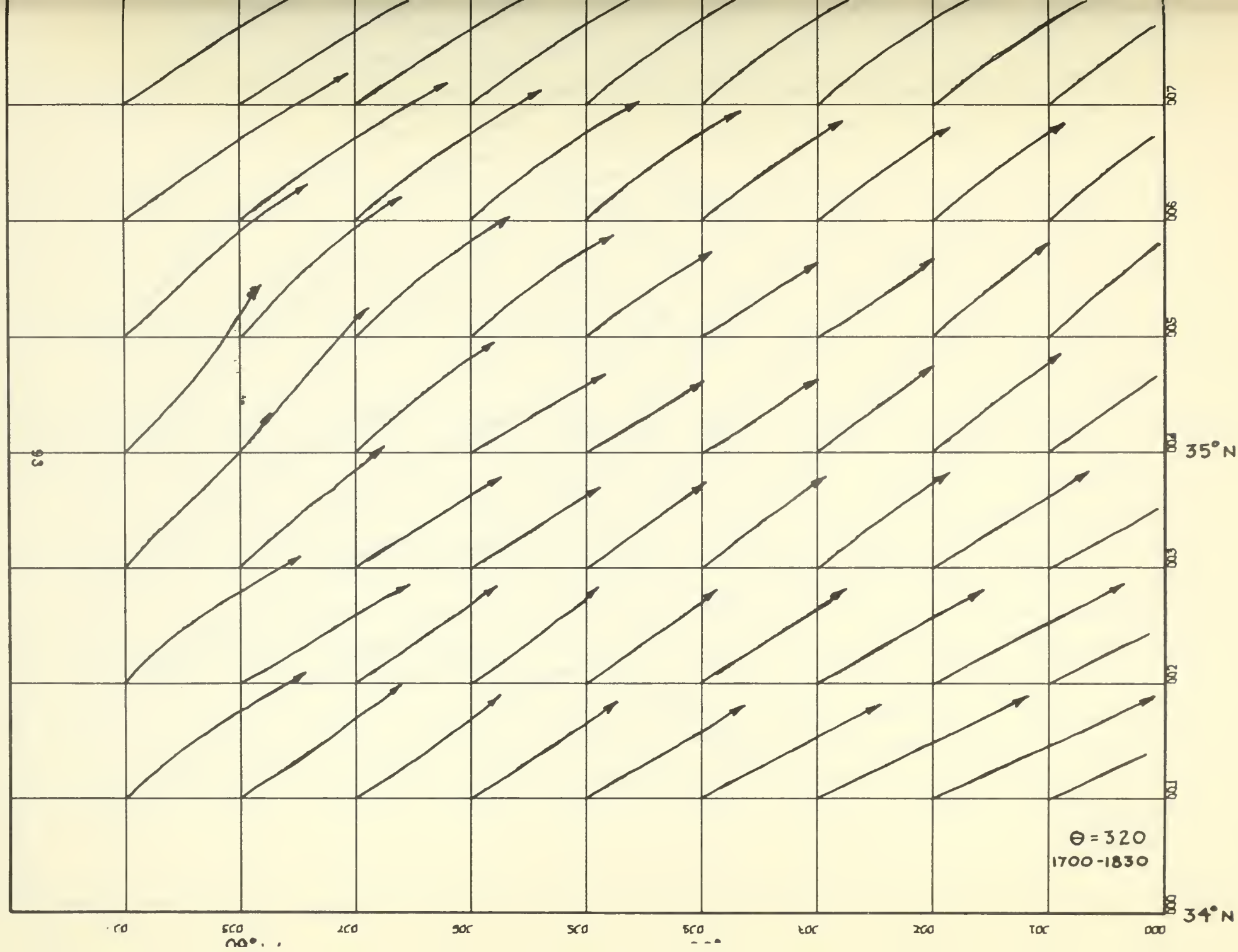

35°N
34°N
Θ=308
2000-2130

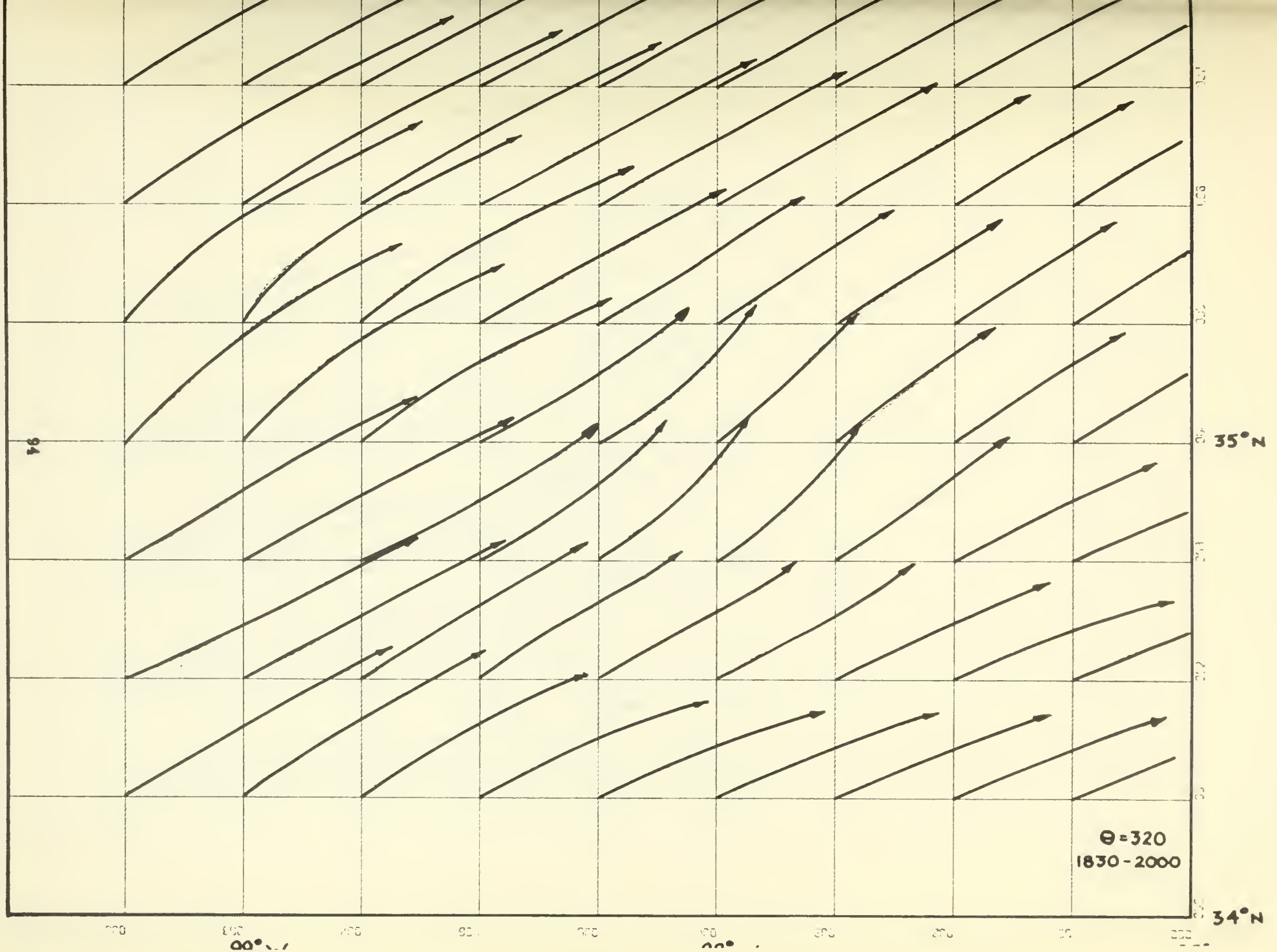
θ = 312
1830-2000
34° N
35° N

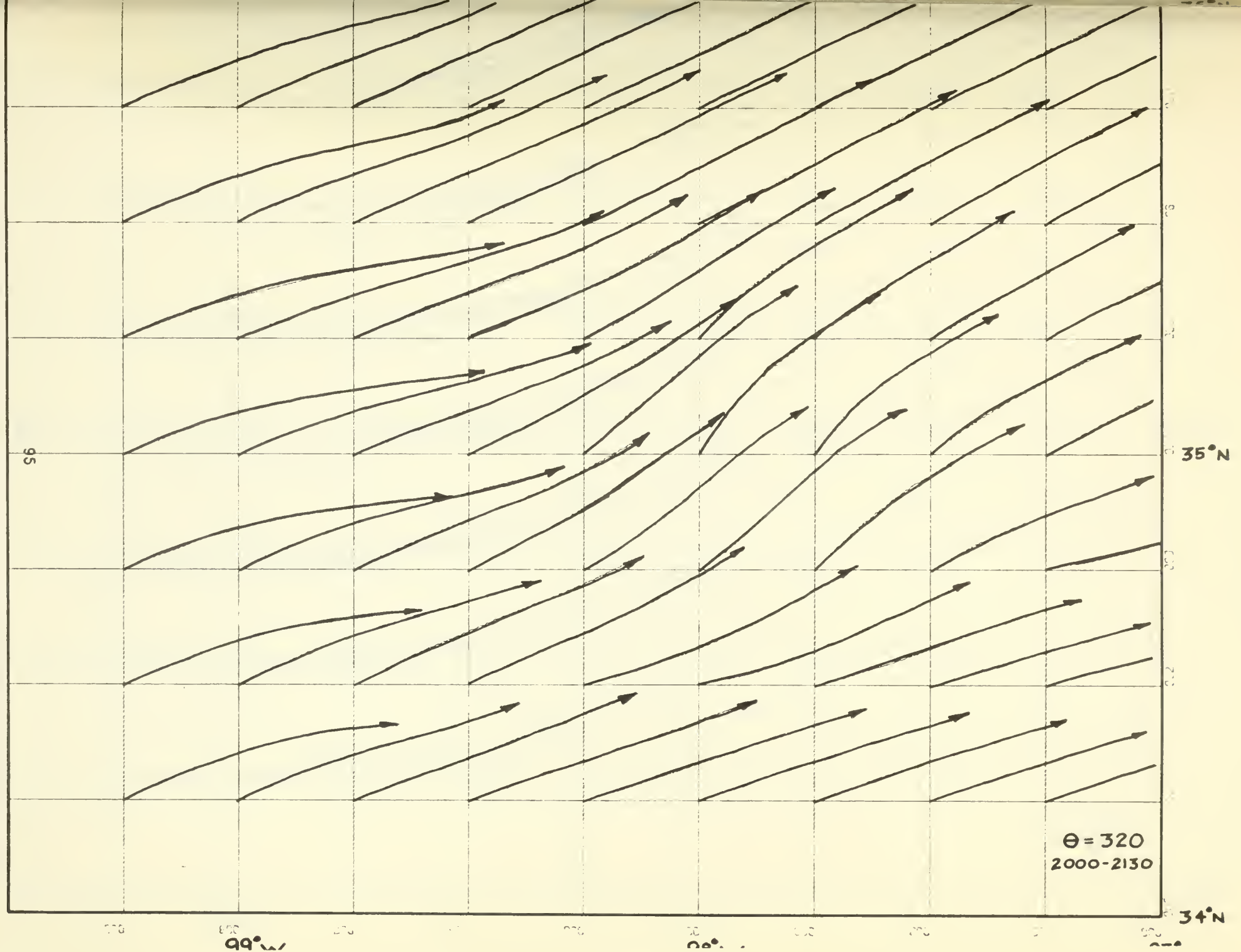

35°N
34°N
Θ = 312
1700 - 1830

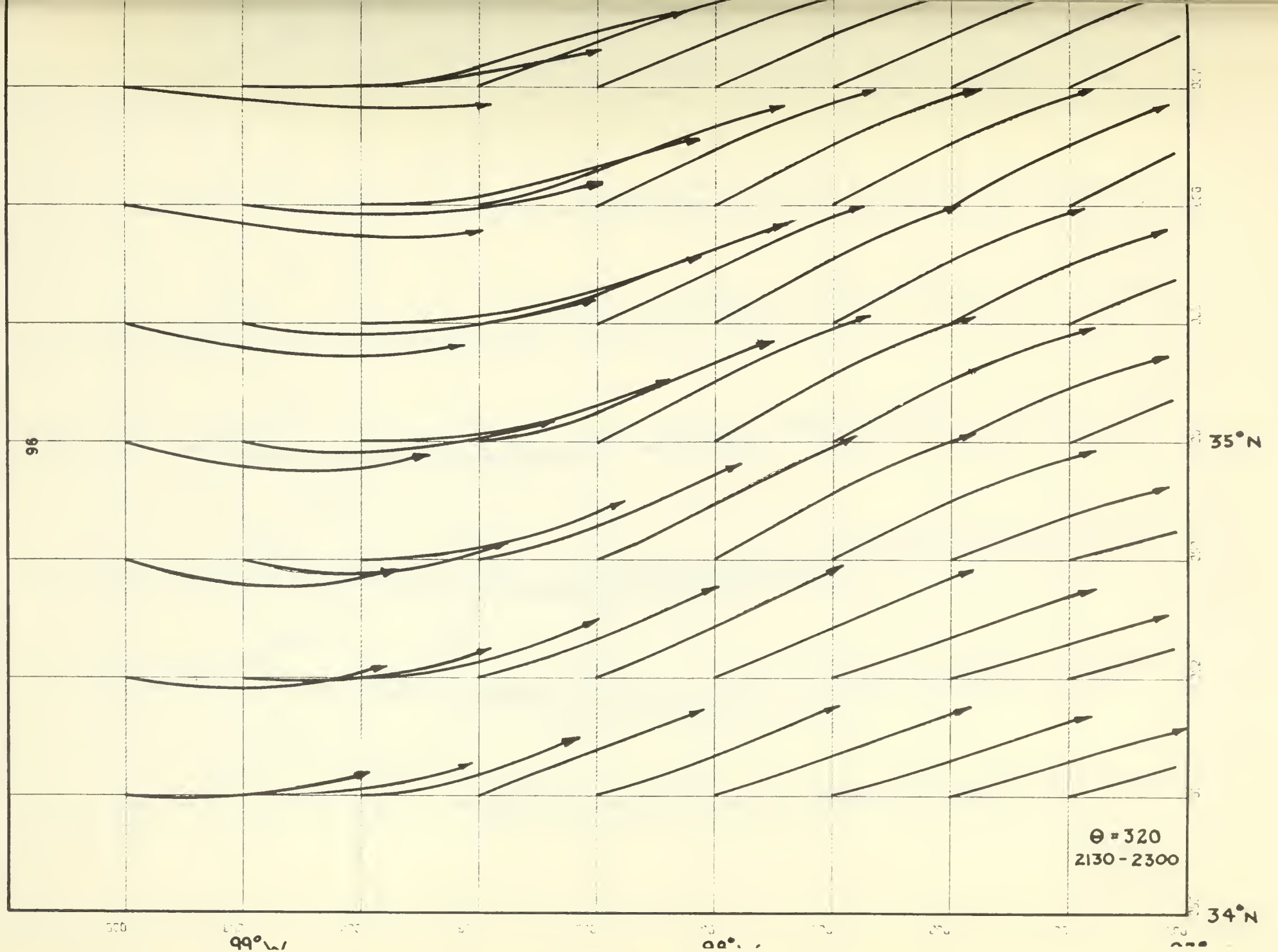

35°N
34°N
Θ = 312
2000 - 2130


35°N
34°N
θ = 312
2130-2300

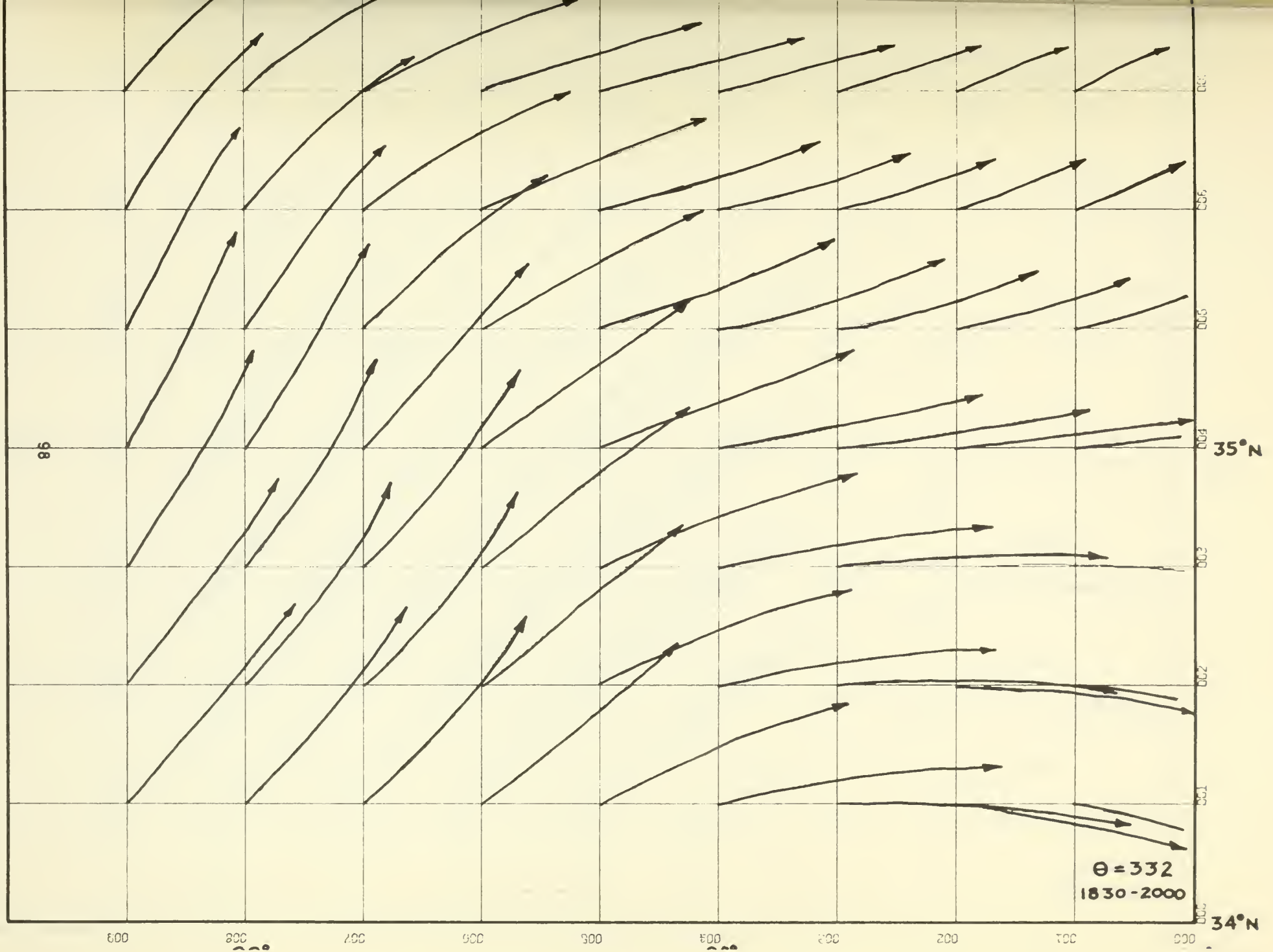

35°N
34°N
Θ = 320
1700-1830

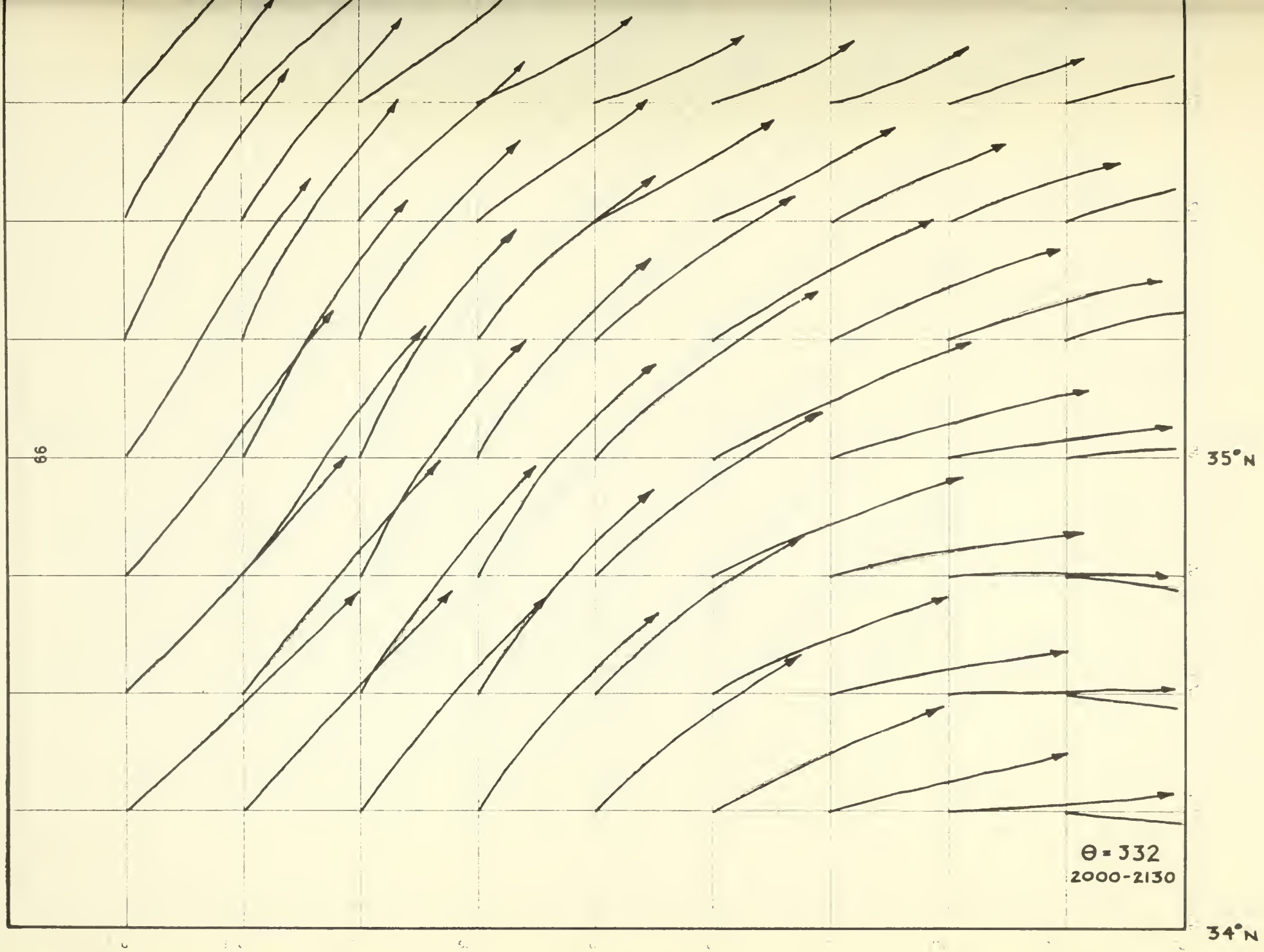

35°N
34°N
Θ=320
1830-2000

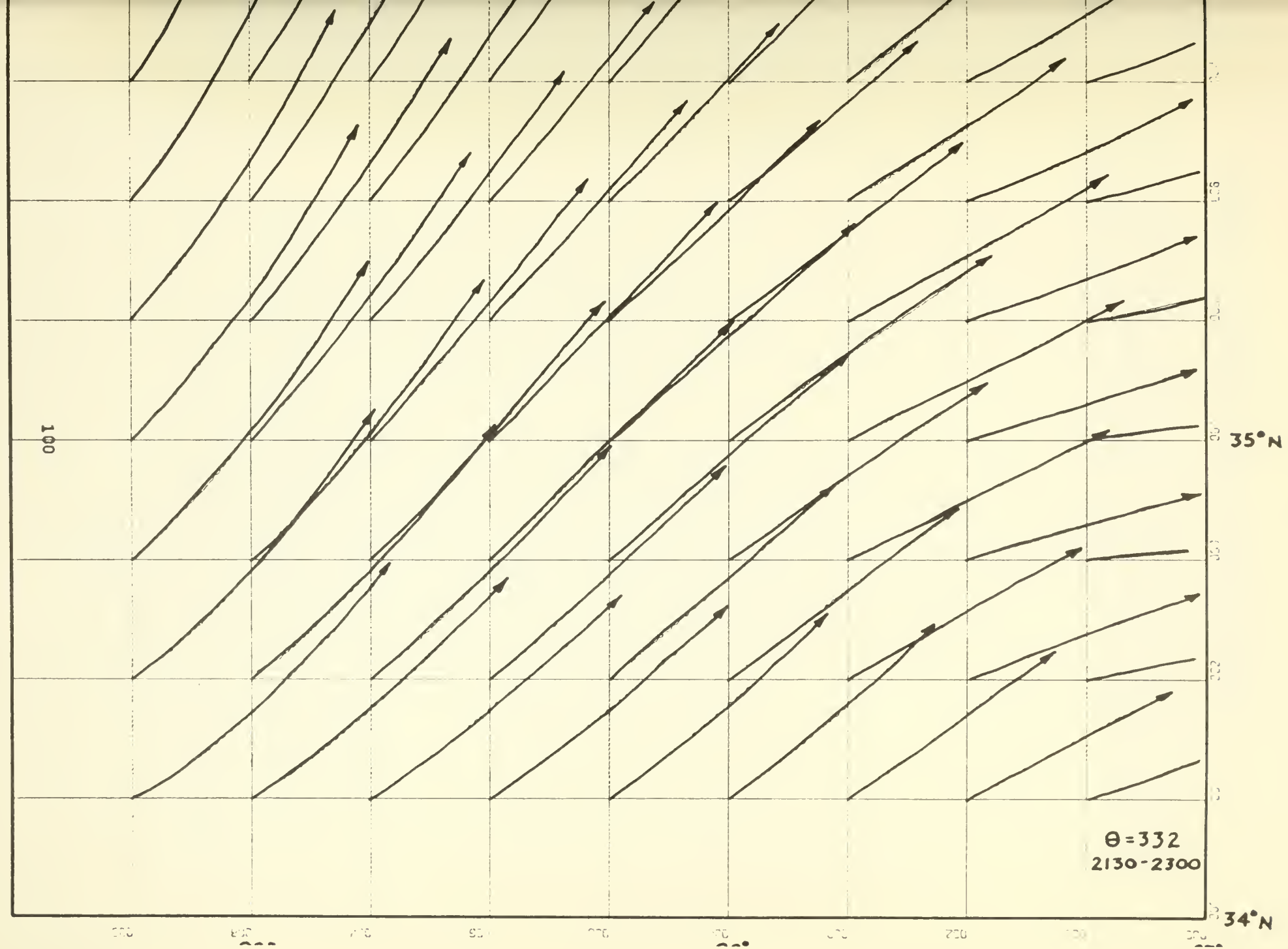

35°N
34°N
99°W
Θ = 320
2000-2130


35°N
34°N
Θ = 320
2130 - 2300

θ=332
1700-1830
35°N
34°N


35°N
34°N
θ = 332
1830 - 2000


66
35°N
34°N
θ = 332
2000-2130


35°N
34°N
θ=332
2130-2300

APPENDIX B - ISENTROPIC TRAJECTORY COMPUTER PROGRAM

This appendix includes the objective computer model. The program is written in FORTRAN language. Each routine contains comment cards which explain the routine and each step.

```
C                                                                       MAI00000
C********************  ISENTROPIC TRAJECTORY STUDY  **********************MAI00010
C                                                                       MAI00020
C                    BASIC DESIGN - J. MAHLMAN, PROF., USNPGS           MAI00030
C                    MODIFIED BY LT K.L. VAN SICKLE,USN                 MAI00040
C****                                                                   MAI00050
C     THIS PROGRAM COMPUTES THREE DIMENSIONAL (KINEMATIC) ISENTROPIC    MAI00060
C     TRAJECTORIES ON AN I,J,K,L LATITUDE-LONGTITUDE GRID; I GRID       MAI00070
C     POINTS ALONG LONGTITUDE LINES, J GRID POINTS ALONG LATITUDE       MAI00080
C     LINES, K GRID POINTS ARE NO. THETA SURFACES AND L ARE THE NO.     MAI00090
C     OF TIME SEQUENCES TO BE CONSIDERED. THE PROGRAM REQUIRES INPUT    MAI00100
C     FIELDS OF: WIND DIRECTION(DEGS FROM),WIND SPEED(M/SEC),MONTGOMERY MAI00110
C     STREAM FUNTION(10**7 ERG/GM),PRESSURE(MB) AND RELATIVE HUMIDITY   MAI00120
C     (%). THE PROGRAM IS BEING RUN ON AN IBM/360 COMPUTER LOCATED AT   MAI00130
C     USNPGS, MONTEREY,CALIF. THE PROGRAM IS CURRENTLY DIMENSIONED FOR   MAI00140
C     A 11,9,2,2 GRID AND WILL PRODUCE 1.5 HOUR TRAJECTORIES. IT IS     MAI00150
C     CURRENTLY USED IN STUDY OF SEVERE STORMS UTILIZING DATA FROM THE  MAI00160
C     SEVERE STORMS NETWORK AT NORMAN, OKLA.                            MAI00170
C****                                                                   MAI00180
      REAL*8 ITITL1                                                     MAI00190
      REAL*8 ITITL2                                                     MAI00200
C                                                                       MAI00210
      COMMON ITITL1(12),ITITL2(12),DD(11,9,2,2),FF(11,9,2,2),F(9),DX(9),MAI00220
     1PSIM(11,9,2,2),U(11,9,2,12),V(11,9,2,12),UO(11,9,2),VO(11,9,2),   MAI00230
     2DMDT1(11,9,2),DMDT2(11,9,2),THSFC(2),U1(12),V1(12),DMDT(12),ALAT  MAI00240
     3(12),ALONG(12),DY,SOULAT,WELONG,NI,NJ,NK,NL,IDATE,DELLAT,DT,DELONGMAI00250
     4,ANJ,U12,V12,ANK,ANI,ANJ,AI,AJ,AK,SUMXD,SUMYD,SDMDT1,YD,XD,NLDAY, MAI00260
     5AAI,AAJ,ALATO,ALONGO,IINC,JINC,AIINC,AJINC,XDIST,YDIST,AAII,AAJJ, MAI00270
     6II,JJ,FINALM,AMINIT,AKINIT,FINALK,DELTAM,I,J,K,L,IZ,JZ,Z1(12),PSATMAI00280
     7,PINIT,PFINAL,OMEGA,P(11,9,2,2),VINIT,VFINAL,ACCEL,IMET1,IMET2    MAI00290
     8,COUNT,X(12),Y(12),MODCUR,SHDEF(11,9,2,2),STAB(11,9,2),ZO(11,9,2),MAI00300
     9DIV(11,9,2,2),STDEF(11,9,2,2),VORT(11,9,2,2),AVORT(11,9,2,2),ENGITMAI00310
     *,SPD(2),CRS(2),SMU(2),SMV(2),QS(11,9,2,2),QSINIT,QFINL,QSFINL,    MAI00320
     1RH(11,9,2,2),Q(11,9,2,2),VOFINL,DFINL,VOINT,DINIT,DIFF,QINIT,     MAI00330
     2T(11,9,2,2),TD(11,9,2,2),E(11,9,2,2),ES(11,9,2,2),Z(11,9,2,12)    MAI00340
     3,STABI,STABF,PVORTI,PVORTF,POTDIF,QDIF                            MAI00341
C                                                                       MAI00350
      CALL READ                                                         MAI00360
      CALL CONST                                                        MAI00370
      CALL PRAM                                                         MAI00380
      CALL STABLE                                                       MAI00390
      CALL MOIST                                                        MAI00400
      CALL INTERP                                                       MAI00410
      CALL TRAJ                                                         MAI00420
C****                                                                   MAI00430
C     SUBROUTINE ENERGY IS CALLED IN SUBROUTINE TRAJ                    MAI00440
C****                                                                   MAI00450
C                                                                       MAI00460
```

```
      STOP                                                              MAIC0470
      END                                                               MAIC0480


      SUBROUTINE READ                                                   REDC0500
C****                                                                   REDC0510
C     THIS SUBRCUTINE READS IN BASIC DATA AND CCNVERTS TO U AND V FIELDSREDC0520
C****                                                                   REDC0530
      REAL*8 ITITL1                                                     REDC0540
      REAL*8 ITITL2                                                     REDC0550
C                                                                       REDC0560
      COMMCN ITITL1(12),ITITL2(12),DD(11,9,2,2),FF(11,9,2,2),F(9),DX(9),REDC0570
     1PSIM(11,9,2,2),U(11,9,2,12),V(11,9,2,12),UO(11,9,2),VO(11,9,2),   REDC0580
     2DMDT1(11,9,2),DMDT2(11,9,2),THSFC(2),U1(12),V1(12),DMDT(12),ALAT  REDC0590
     3(12),ALCNG(12),DY,SCULAT,WELONG,NI,NJ,NK,NL,IDATE,DELLAT,DT,DELONGREDC0600
     4,ANJ,U12,V12,NNK,NNI,NNJ,AI,AJ,AK,SUMXD,SUMYD,SDMDT1,YD,XD,NLDAY, REDC0610
     5AAI,AAJ,ALATC,ALONGC,IINC,JINC,AIINC,AJINC,XDIST,YDIST,AAII,AAJJ, REDC0620
     6II,JJ,FINALM,AMINIT,AKINIT,FINALK,DELTAM,I,J,K,L,IZ,JZ,Z1(12),PSATREDC0630
     7,PINIT,PFINAL,OMEGA,P(11,9,2,2),VINIT,VFINAL,ACCEL,IMET1,IMET2    REDC0640
     8,COUNT,X(12),Y(12),MODCUR,SHDEF(11,9,2,2),STAB(11,9,2),ZO(11,9,2),REDC0650
     9DIV(11,9,2,2),STDEF(11,9,2,2),VCRT(11,9,2,2),AVCRT(11,9,2,2),ENGITREDC0660
     *,SPD(2),CRS(2),SMU(2),SMV(2),QS(11,9,2,2),QSINIT,QFINL,QSFINL,    REDC0670
     1FH(11,9,2,2),Q(11,9,2,2),VOFINL,DFINL,VCINT,DINIT,DIFF,QINIT,     REDC0680
     2T(11,9,2,2),TD(11,9,2,2),E(11,9,2,2),ES(11,9,2,2),Z(11,9,2,12)    REDC0690
     3,STABI,STABF,PVORTI,PVORTF,POTDIF,QDIF                            REDC0691
C****                                                                   REDC0700
C     READ IN TITLE INFORMATION FCR GRAPHIC DISPLAY                     REDC0710
C****                                                                   REDC0720
      READ(5,200)(ITITL1(I),I=1,12)                                     REDC0730
      READ(5,200)(ITITL2(I),I=1,12)                                     REDC0740
  200 FORMAT(6A8)                                                       REDC0750
C****                                                                   REDC0760
C     READ IN DISTANCE BETWEEN GRID PCINTS(METERS);SOUTHERN LAT. OF GRIDREDC0770
C     AND WESTERN LONG. OF GRID;I,J,K,L VALUES                          REDC0780
C****                                                                   REDC0790
      READ (5,1) DY,SCULAT,WELONG,NI,NJ,NK,NL                           REDC0800
    1 FORMAT(5X,F7.0,3X,F5.2,3X,F6.2,3X,I3,3X,I3,3X,I3,3X,I3)           REDC0810
C****                                                                   REDC0820
C     READ IN DATE INFO(MCNTH,DAY,YEAR);DISTANCE BETWEEN LAT. GRID POINTREDC0830
C     (DEGS);INTERVAL BETWEEN TIME STEPS;DISTANCE BETWEEN LONG. PCINTS  REDC0840
C****                                                                   REDC0850
      READ(5,2)IDATE,DELLAT,DT,DELONG                                   REDC0860
    2 FORMAT(5X,I8,3X,F4.2,3X,F3.1,3X,F4.2)                             REDC0870
C                                                                       REDC0880
 1000 FORMAT(1H1)                                                       REDC0890
      WRITE(6,999)                                                      REDC0900
```

```
  999 FORMAT(2X,'    DY   SOULAT       WELONG     NI    NJ    NK    NL ',//)REDC0910
      WRITE(6,1) DY,SCULAT,WELONG,NI,NJ,NK,NL                              REDC0920
      WRITE(6,998)                                                         REDC0930
  998 FORMAT(2X,'    IDATE    DELLAT    DT       DELONG',//)               REDC0940
      WRITE(6,2) IDATE,DELLAT,DT,DELONG                                    REDC0950
C****                                                                      REDC0960
C     READ IN PCTENTIAL TEMPERATURE SURFACES TO BE USED                    REDC0970
C****                                                                      REDC0980
      READ(5,3) (THSFC(K),K=1,NK)                                          REDC0990
    3 FORMAT(3X,2F6.1)                                                     REDC1000
C****                                                                      REDC1010
C     ROUTINE TO OBTAIN TIMES OF DATA FOR OUTPUT DISPLAY                   REDC1020
C     IMET1,ETC. ARE NAMES FOR TIMES OF DATA                               REDC1030
C****                                                                      REDC1040
      READ(5,500) MITE                                                     REDC1050
  500 FORMAT(3X,I1)                                                        REDC1060
      IF(MITE.EQ.1) GO TO 201                                              REDC1070
      IF(MITE.EQ.2) GO TO 202                                              REDC1080
      IF(MITE.EQ.3) GO TO 203                                              REDC1090
      IF(MITE.EQ.4) GO TO 204                                              REDC1100
  201 IMET1 = 1700                                                         REDC1110
      IMET2 = 1830                                                         REDC1120
      GO TO 205                                                            REDC1130
  202 IMET1 = 1830                                                         REDC1140
      IMET2 = 2000                                                         REDC1150
      GO TO 205                                                            REDC1160
  203 IMET1 = 2000                                                         REDC1170
      IMET2 = 2130                                                         REDC1180
      GO TO 205                                                            REDC1190
  204 IMET1 = 2130                                                         REDC1200
      IMET2 = 2300                                                         REDC1210
      GO TO 205                                                            REDC1220
  205 CONTINUE                                                             REDC1230
C****                                                                      REDC1240
C     ROUTINE TO INCLUDE STORM MOVEMENT TO OBTAIN TRAJECTORIES RELATIVE    REDC1250
C     TO THE STORM. READ IN AS 000 AND 0.0 IF TRUE TRAJECTORIES ARE        REDC1260
C     DESIRED                                                              REDC1270
C****                                                                      REDC1280
      READ(5,300)(SPD(K),K=1,NK)                                           REDC1290
  300 FORMAT(2F6.2)                                                        REDC1300
      READ(5,300)(CRS(K),K=1,NK)                                           REDC1310
C****                                                                      REDC1320
C     READ IN BASIC DATA                                                   REDC1330
C****                                                                      REDC1340
      DO 4 L=1,NL                                                          REDC1350
      DO 4 K=1,NK                                                          REDC1360
      DO 4 I=1,NI                                                          REDC1370
    4 READ(5,5) (DD(I,J,K,L),J=1,NJ)                                       REDC1380
```

```
    5 FORMAT(20F4.0)                                                    REDC1390
C                                                                       REDC1400
      DO 6 L=1,NL                                                       REDC1410
      DO 6 K=1,NK                                                       REDC1420
      DO 6 I=1,NI                                                       REDC1430
    6 READ(5,55) (FF(I,J,K,L),J=1,NJ)                                   REDC1440
   55 FORMAT(20F4.1)                                                    REDC1450
C                                                                       REDC1460
      DO 7 L=1,NL                                                       REDC1470
      DO 7 K=1,NK                                                       REDC1480
      DO 7 I=1,NI                                                       REDC1490
    7 READ(5,8) (PSIM(I,J,K,L),J=1,NJ)                                  REDC1500
    8 FORMAT(15F5.2)                                                    REDC1510
C                                                                       REDC1520
      DO 12 L=1,NL                                                      REDC1530
      DO 12 K=1,NK                                                      REDC1540
      DO 12 I=1,NI                                                      REDC1550
      DO 12 J=1,NJ                                                      REDC1560
      IF(PSIM(I,J,K,L) .LT. 80.)PSIM(I,J,K,L)=PSIM(I,J,K,L) + 300.      REDC1570
      IF(PSIM(I,J,K,L) .LT. 100.)PSIM(I,J,K,L)=PSIM(I,J,K,L) + 200.     REDC1580
   12 CONTINUE                                                          REDC1590
C                                                                       REDC1600
      DO 105 L=1,NL                                                     REDC1610
      DO 105 K=1,NK                                                     REDC1620
      DO 105 I=1,NI                                                     REDC1630
  105 READ(5,106) (P(I,J,K,L),J=1,NJ)                                   REDC1640
  106 FORMAT(19F4.0)                                                    REDC1650
C                                                                       REDC1660
      DO 107 L=1,NL                                                     REDC1670
      DO 107 K=1,NK                                                     REDC1680
      DO 107 I=1,NI                                                     REDC1690
  107 READ(5,108)(RH(I,J,K,L),J=1,NJ)                                   REDC1700
  108 FORMAT(15F5.1)                                                    REDC1710
C****                                                                   REDC1720
C     COMPUTE U AND V COMPONENTS OF STORM MOTION                        REDC1730
C****                                                                   REDC1740
      DO 301 K=1,NK                                                     REDC1750
      SMU(K) = -SPD(K)*SIN(CRS(K)/57.2958)                              REDC1760
      SMV(K) = -SPD(K)*COS(CRS(K)/57.2958)                              REDC1770
  301 CONTINUE                                                          REDC1780
C****                                                                   REDC1790
C     COMPUTE U AND V FIELDS                                            REDC1800
C****                                                                   REDC1810
      DO 15 L=1,NL                                                      REDC1820
      DO 15 K=1,NK                                                      REDC1830
      DO 15 J=1,NJ                                                      REDC1840
      DO 15 I=1,NI                                                      REDC1850
      U(I,J,K,L)=-FF(I,J,K,L)*SIN(DD(I,J,K,L)/57.2958) - SMU(K)         REDC1860
```

```
   15 V(I,J,K,L)=-FF(I,J,K,L)*COS(DD(I,J,K,L)/57.2958) - SMV(K)          RED01870
C****                                                                   RED01880
C      WRITE OUT VARIABLES READ IN                                      RED01890
C****                                                                   RED01900
       DO 20 L=1,NL                                                     RED01910
       DO 20 K=1,NK                                                     RED01920
       IF(L.EQ.1)IMET = IMET1                                           RED01930
       IF(L.EQ.2)IMET = IMET2                                           RED01940
       WRITE(6,1000)                                                    RED01950
       WRITE(6,9)IMET,THSFC(K),IDATE                                    RED01960
    9  FORMAT(3X,'WIND DIRECTION FOR TIME =',I4,' AND FOR THETA =',F7.1,'RED01970
      1 DATE =',I6,////)                                                RED01980
       DO 100 J=1,NJ                                                    RED01990
  100  WRITE(6,10) (DD(I,NJ-J+1,K,L),I=1,NI)                            RED02000
C                                                                       RED02010
       WRITE(6,1000)                                                    RED02020
       WRITE(6,13)IMET,THSFC(K),IDATE                                   RED02030
   13  FORMAT(3X,'MONTGOMERY STREAM FUNCTION (10**7 ERG/G) FOR TIME =',I4RED02040
     1,' AND FOR THETA =',F7.1,' DATE =',I6,////)                       RED02050
       DO 101 J=1,NJ                                                    RED02060
  101  WRITE(6,14) (PSIM(I,NJ-J+1,K,L),I=1,NI)                          RED02070
C                                                                       RED02080
       WRITE(6,1000)                                                    RED02090
       WRITE(6,11)IMET,THSFC(K),IDATE                                   RED02100
   11  FORMAT(3X,'WIND SPEED (M/SEC) FOR TIME =',I4,' AND FOR THETA =',F7RED02110
     1.1,' DATE =',I6,////)                                             RED02120
       DO 102 J=1,NJ                                                    RED02130
  102  WRITE(6,10) (FF(I,NJ-J+1,K,L),I=1,NI)                            RED02140
C                                                                       RED02150
       WRITE(6,1000)                                                    RED02160
       WRITE(6,23)IMET,THSFC(K),IDATE                                   RED02170
   23  FORMAT(3X,'PRESSURE (MB) FOR TIME =',I4,' AND FOR THETA =',F7.1,' RED02180
     1DATE =',I6,////)                                                  RED02190
       DO 24 J=1,NJ                                                     RED02200
   24  WRITE(6,10) (P(I,NJ-J+1,K,L),I=1,NI)                             RED02210
C                                                                       RED02220
   20  CONTINUE                                                         RED02230
C****                                                                   RED02240
C      THESE FORMAT STATEMENTS ARE SET FOR A ONE INCH BY ONE INCH GRID. RED02250
C****                                                                   RED02260
   10  FORMAT(2X,11F10.1,///////)                                       RED02270
   14  FORMAT(2X,11F10.2,///////)                                       RED02280
C                                                                       RED02290
       DO 18 L=1,NL                                                     RED02300
       DO 18 K=1,NK                                                     RED02310
       IF(L.EQ.1)IMET = IMET1                                           RED02320
       IF(L.EQ.2)IMET = IMET2                                           RED02330
       WRITE (6,1000)                                                   RED02340
```

```
      WRITE(6,16)IMET,THSFC(K),IDATE                                    REDC2350
   16 FORMAT(3X,'U COMPONENT OF WIND (M/SEC) FOR TIME =',I4,' AND FOR THREDC2360
     1ETA =',F7.1,' DATE =',I6,/)                                       REDC2370
      DO 103 J=1,NJ                                                     REDC2380
  103 WRITE(6,14) (U(I,NJ-J+1,K,L),I=1,NI)                              REDC2390
C                                                                       REDC2400
      WRITE(6,1000)                                                     REDC2410
      WRITE(6,17)IMET,THSFC(K),IDATE                                    REDC2420
   17 FORMAT(3X,'V COMPONENT OF WIND (M/SEC) FOR TIME =',I4,' AND FOR THREDC2430
     1ETA =',F7.1,' DATE =',I6,/)                                       REDC2440
      DO 104 J=1,NJ                                                     REDC2450
  104 WRITE(6,14) (V(I,NJ-J+1,K,L),I=1,NI)                              REDC2460
C                                                                       REDC2470
      WRITE(6,1000)                                                     REDC2480
      WRITE(6,50)IMET,THSFC(K),IDATE                                    REDC2490
   50 FORMAT(3X,'RELATIVE HUMIDITY(%) FOR TIME =',I4,' AND FOR THETA =',REDC2500
     1F7.1,' DATE =',I6,////)                                           REDC2510
      DO 71 J=1,NJ                                                     REDC2520
   71 WRITE(6,70) (RH(I,NJ-J+1,K,L),I=1,NI)                            REDC2530
   70 FORMAT(2X,11F10.3,///////)                                        REDC2540
C                                                                       REDC2550
   18 CONTINUE                                                          REDC2560
C                                                                       REDC2570
      WRITE(6,1000)                                                     REDC2580
      WRITE(6,302)                                                      REDC2590
  302 FORMAT(//,2X,'U COMPONENT OF STORM MOVEMENT',//)                  REDC2600
      WRITE(6,303) (SMU(K),K=1,NK)                                      REDC2610
  303 FORMAT(2X,2F6.2)                                                  REDC2620
      WRITE(6,304)                                                      REDC2630
  304 FORMAT(//,2X,'V COMPONENT OF STORM MOVEMENT',//)                  REDC2640
      WRITE(6,303) (SMV(K),K=1,NK)                                      REDC2650
C                                                                       REDC2660
      RETURN                                                            REDC2670
      END                                                               REDC2680


      SUBROUTINE CONST                                                  CSTC2690
C****                                                                   CSTC2700
C     THIS SUBROUTINE COMPUTES Y-DEPENDENT PARAMETERS FOR THE CARTESIAN CSTC2710
C     GRID                                                              CSTC2720
C****                                                                   CSTC2730
      REAL*8 ITITL1                                                     CSTC2740
      REAL*8 ITITL2                                                     CSTC2750
C                                                                       CST02760
      COMMON ITITL1(12),ITITL2(12),DD(11,9,2,2),FF(11,9,2,2),F(9),DX(9),CSTC277C
     1PSIM(11,9,2,2),U(11,9,2,12),V(11,9,2,12),U0(11,9,2),V0(11,9,2),   CST02780
```

```
     2DMDT1(11,9,2),DMDT2(11,9,2),THSFC(2),U1(12),V1(12),DMDT(12),ALAT  CST02790
     3(12),ALONG(12),DY,SOULAT,WELONG,NI,NJ,NK,NL,IDATE,DELLAT,DT,DELONGCST02800
     4,ANJ,U12,V12,NNK,NNI,NNJ,AI,AJ,AK,SUMXD,SUMYD,SDMDT1,YD,XD,NLDAY, CST02810
     5AAI,AAJ,ALATO,ALONGO,IINC,JINC,AIINC,AJINC,XDIST,YDIST,AAII,AAJJ, CST02820
     6II,JJ,FINALM,AMINIT,AKINIT,FINALK,DELTAM,I,J,K,L,IZ,JZ,Z1(12),PSATCST02830
     7,PINIT,PFINAL,OMEGA,P(11,9,2,2),VINIT,VFINAL,ACCEL,IMET1,IMET2    CST02840
     8,COUNT,X(12),Y(12),MODCUR,SHDEF(11,9,2,2),STAB(11,9,2),ZO(11,9,2),CST02850
     9DIV(11,9,2,2),STDEF(11,9,2,2),VORT(11,9,2,2),AVORT(11,9,2,2),ENGITCST02860
     *,SPD(2),CRS(2),SMU(2),SMV(2),QS(11,9,2,2),QSINIT,QFINL,QSFINL,    CST02870
     1RH(11,9,2,2),Q(11,9,2,2),VOFINL,DFINL,VOINT,DINIT,DIFF,QINIT,     CST02880
     2T(11,9,2,2),TD(11,9,2,2),E(11,9,2,2),ES(11,9,2,2),Z(11,9,2,12)    CST02890
     3,STABI,STABF,PVORTI,PVORTF,POTDIF,QDIF                            CST02891
C                                                                       CST02900
      WRITE(6,1000)                                                     CST02910
 1000 FORMAT(1H1)                                                       CST02920
      SSSLAT = SOULAT                                                   CST02930
      WRITE(6,2)                                                        CST02940
    2 FORMAT(4X,'LATITUDE',10X,'CORIOLIS PARAMETER',15X,'DX(J)',//)     CST02950
      DO 1 J=1,NJ                                                       CST02960
      DX(J)=DY*COS(SOULAT/57.2958)                                      CST02970
C****                                                                   CST02980
C     COMPUTE CORIOLIS PARAMETER                                        CST02990
C****                                                                   CST03000
      F(J)=14.58*SIN(SOULAT/57.2958)                                    CST03010
      WRITE(6,3) SOULAT,F(J),DX(J)                                      CST03020
    1 SOULAT=SOULAT + DELLAT                                            CST03030
    3 FORMAT(6X,F5.2,18X,F5.2,15X,F9.1,//)                              CST03040
      SOULAT = SSSLAT                                                   CST03050
C                                                                       CST03060
      RETURN                                                            CST03070
      END                                                               CST03080



      SUBROUTINE PRAM                                                   PRMC3090
C****                                                                   PRM03100
C     THIS SUBROUTINE WILL COMPUTE HORIZONTAL DIVERGENCE, VORTICITY,    PRM03110
C     STRETCHING DEFORMATION AND SHEARING DEFORMATION TERMS.            PRM03120
C****                                                                   PRM03130
      REAL*8 ITITL1                                                     PRM03140
      REAL*8 ITITL2                                                     PRM03150
C                                                                       PRM03160
      COMMON ITITL1(12),ITITL2(12),DD(11,9,2,2),FF(11,9,2,2),F(9),DX(9),PRM03170
     1PSIM(11,9,2,2),U(11,9,2,12),V(11,9,2,12),UO(11,9,2),VO(11,9,2),   PRM03180
     2DMDT1(11,9,2),DMDT2(11,9,2),THSFC(2),U1(12),V1(12),DMDT(12),ALAT  PRM03190
     3(12),ALONG(12),DY,SOULAT,WELONG,NI,NJ,NK,NL,IDATE,DELLAT,DT,DELONGPRM03200
     4,ANJ,U12,V12,NNK,NNI,NNJ,AI,AJ,AK,SUMXD,SUMYD,SDMDT1,YD,XD,NLDAY, PRM03210
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     5AAI,AAJ,ALATC,ALONGO,IINC,JINC,AIINC,AJINC,XDIST,YDIST,AAII,AAJJ,  PRM03220
     6II,JJ,FINALM,AMINIT,AKINIT,FINALK,DELTAM,I,J,K,L,IZ,JZ,Z1(12),PSATPRM03230
     7,PINIT,PFINAL,OMEGA,P(11,9,2,2),VINIT,VFINAL,ACCEL,IMET1,IMET2    PRM03240
     8,COUNT,X(12),Y(12),MODCUR,SHDEF(11,9,2,2),STAB(11,9,2),ZO(11,9,2),PRM03250
     9DIV(11,9,2,2),STDEF(11,9,2,2),VORT(11,9,2,2),AVORT(11,9,2,2),ENGITPRM03260
     *,SPD(2),CRS(2),SMU(2),SMV(2),QS(11,9,2,2),QSINIT,QFINL,QSFINL,    PRM03270
     1RH(11,9,2,2),Q(11,9,2,2),VOFINL,DFINL,VOINIT,DINIT,DIFF,QINIT,    PRM03280
     2T(11,9,2,2),TD(11,9,2,2),E(11,9,2,2),ES(11,9,2,2),Z(11,9,2,12)    PRM03290
     3,STABI,STABF,PVORTI,PVORTF,POTDIF,QCIF                            PRM03291
C                                                                       PRM03300
      MI = NI-1                                                         PRM03310
      MJ = NJ-1                                                         PRM03320
      DO 5 L=1,NL                                                       PRM03330
      DO 5 K=1,NK                                                       PRM03340
      DO 5 J=2,MJ                                                       PRM03350
      DO 5 I=2,MI                                                       PRM03360
C****                                                                   PRM03370
C     COMPUTE U AND V COMPONENTS OF DIVERGENCE.                         PRM03380
C****                                                                   PRM03390
      DVCOMP = (V(I,J+1,K,L)-V(I,J-1,K,L))/(DY*2.)                      PRM03400
      DUCOMP = (U(I+1,J,K,L)-U(I-1,J,K,L))/(DX(J)*2.)                   PRM03410
C****                                                                   PRM03420
C     COMPUTE DIVERGENCE(MULTIPLY BY 10000 TO CUTOFF 10**-4).           PRM03430
C****                                                                   PRM03450
      DIV(I,J,K,L) = (DUCOMP+DVCOMP)*10000.                             PRM03460
C****                                                                   PRM03470
C     COMPUTE STRETCHING DEFORMATION(MULTIPLY BY 10000 TO CUTOFF 10**-4)PRM03480
C****                                                                   PRM03490
      STDEF(I,J,K,L) = (DUCOMP-DVCOMP)*10000.                           PRM03500
C****                                                                   PRM03510
C     COMPUTE U AND V COMPONENTS OF VORTICITY.                          PRM03520
C****                                                                   PRM03530
      VUCOMP = (U(I,J+1,K,L)-U(I,J-1,K,L))/(DY*2.)                      PRM03540
      VVCOMP = (V(I+1,J,K,L)-V(I-1,J,K,L))/(DX(J)*2.)                   PRM03550
C****                                                                   PRM03560
C     COMPUTE RELATIVE VORTICITY(MULTIPLY BY 10000 TO CUTOFF 10**-4)    PRM03570
C****                                                                   PRM03580
      VORT(I,J,K,L) = (VVCOMP-VUCOMP)*10000.                            PRM03590
C****                                                                   PRM03600
C     COMPUTE ABSOLUTE VORTICITY.                                       PRM03610
C****                                                                   PRM03620
      AVORT(I,J,K,L) = VORT(I,J,K,L) + F(J)*0.10                        PRM03630
C****                                                                   PRM03640
C     COMPUTE SHEARING DEFORMATION(MULTIPLY BY 10000 TO CUTOFF 10**-4). PRM03650
C****                                                                   PRM03660
      SHDEF(I,J,K,L) = (VVCOMP + VUCOMP)*10000.                         PRM03670
C                                                                       PRM03680
    5 CONTINUE                                                          PRM03690
```

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C****                                                                   PRMC3700
C       WRITE OUT FIELDS                                                PRM03710
C****                                                                   PRM03720
        DO 6 L=1,NL                                                     PRM03730
        DO 6 K=1,NK                                                     PRM03740
        IF(L.EQ.1)IMET=IMET1                                            PRM03750
        IF(L.EQ.2)IMET=IMET2                                            PRM03760
        WRITE(6,1000)                                                   PRM03770
 1000 FORMAT(1H1)                                                       PRM03780
        WRITE(6,7)IMET,THSFC(K),IDATE                                   PRM03790
    7 FORMAT(3X,'HORIZONTAL DIVERGENCE(10**-4 1/SEC) FOR TIME= ',I4,' ANPRM03800
     1D FOR THETA= ',F7.1,' DATE= ',I6,////)                            PRM03810
        DO 8 J=2,MJ                                                    PRM03820
    8 WRITE(6,9) (DIV(I,MJ-J+2,K,L),I=2,MI)                            PRM03830
    9 FORMAT(2X,9F10.2,///////)                                         PRM03840
C                                                                       PRM03850
        WRITE(6,1000)                                                   PRM03860
        WRITE(6,10)IMET,THSFC(K),IDATE                                  PRM03870
   10 FORMAT(3X,'HORIZONTAL ABSOLUTE VORTICITY(10**-4 1/SEC) FOR TIME= 'PRM03880
     1,I4,' AND FOR THETA= ',F7.1,' DATE= ',I6,////)                    PRM03890
        DO 11 J=2,MJ                                                   PRM03900
   11 WRITE(6,9) (AVORT(I,MJ-J+2,K,L),I=2,MI)                          PRM03910
C                                                                       PRM03920
        WRITE(6,1000)                                                   PRM03930
        WRITE(6,12)IMET,THSFC(K),IDATE                                  PRM03940
   12 FORMAT(3X,'STRETCHING DEFORMATION(10**-4 1/SEC) FOR TIME= ',I4,' APRM03950
     1ND FOR THETA= ',F7.1,' DATE= ',I6,////)                           PRM03960
        DO 13 J=2,MJ                                                   PRM03970
   13 WRITE(6,9) (STDEF(I,MJ-J+2,K,L),I=2,MI)                          PRM03980
C                                                                       PRM03990
        WRITE(6,1000)                                                   PRM04000
        WRITE(6,14)IMET,THSFC(K),IDATE                                  PRM04010
   14 FORMAT(3X,'SHEARING DEFORMATION(10**-4 1/SEC) FOR TIME= ',I4,' ANDPRM04020
     1 FOR THETA= ',F7.1,' DATE= ',I6,////)                             PRM04030
        DO 15 J=2,MJ                                                   PRM04050
   15 WRITE(6,9) (SHDEF(I,MJ-J+2,K,L),I=2,MI)                          PRM04060
    6 CONTINUE                                                          PRM04070
C                                                                       PRM04080
        RETURN                                                          PRM04090
        END                                                             PRM04100
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      SUBROUTINE STABLE                                                 STB04110
C****                                                                   STB04120
C     THIS SUBROUTINE COMPUTES STATIC STABILITY GIVEN THE THETA SURFACESTB04130
C     AND PRESSURES                                                     STB04140
C****                                                                   STB04150
      REAL*8 ITITL1                                                     STB04160
      REAL*8 ITITL2                                                     STB04170
C                                                                       STB04180
      COMMON ITITL1(12),ITITL2(12),DD(11,9,2,2),FF(11,9,2,2),F(9),DX(9),STB04190
     1PSIM(11,9,2,2),U(11,9,2,12),V(11,9,2,12),UO(11,9,2),VO(11,9,2),   STB04200
     2DMDT1(11,9,2),DMDT2(11,9,2),THSFC(2),U1(12),V1(12),DMDT(12),ALAT  STB04210
     3(12),ALONG(12),DY,SOULAT,WELONG,NI,NJ,NK,NL,IDATE,DELLAT,DT,DELONGSTB04220
     4,ANJ,U12,V12,NNK,NNI,NNJ,AI,AJ,AK,SUMXD,SUMYD,SDMDT1,YD,XD,NLDAY, STB04230
     5AAI,AAJ,ALATO,ALONGO,IINC,JINC,AIINC,AJINC,XDIST,YDIST,AAII,AAJJ, STB04240
     6II,JJ,FINALM,AMINIT,AKINIT,FINALK,DELTAM,I,J,K,L,IZ,JZ,Z1(12),PSATSTB04250
     7,PINIT,PFINAL,OMEGA,P(11,9,2,2),VINIT,VFINAL,ACCEL,IMET1,IMET2    STB04260
     8,COUNT,X(12),Y(12),MODCUR,SHDEF(11,9,2,2),STAB(11,9,2),ZO(11,9,2),STB04270
     9DIV(11,9,2,2),STDEF(11,9,2,2),VORT(11,9,2,2),AVORT(11,9,2,2),ENGITSTB04280
     *,SPD(2),CRS(2),SMU(2),SMV(2),QS(11,9,2,2),QSINIT,QFINL,QSFINL,    STB04290
     1RH(11,9,2,2),Q(11,9,2,2),VOFINL,DFINL,VOINT,DINIT,DIFF,QINIT,     STB04300
     2T(11,9,2,2),TD(11,9,2,2),E(11,9,2,2),ES(11,9,2,2),Z(11,9,2,12)    STB04310
     3,STABI,STABF,PVORTI,PVORTF,POTDIF,QDIF                            STB04311
C                                                                       STB04320
 1000 FORMAT(1H1)                                                       STB04330
      K=1                                                               STB04340
      DO 5 L=1,NL                                                       STB04350
      DO 5 I=1,NI                                                       STB04360
      DO 5 J=1,NJ                                                       STB04370
      STAB(I,J,L) = -(THSFC(K+1)-THSFC(K))/(P(I,J,K+1,L)-P(I,J,K,L))    STB04380
    5 CONTINUE                                                          STB04390
C                                                                       STB04400
      M = K+1                                                           STB04410
      DO 30 L=1,NL                                                      STB04420
      IF(L.EQ.1)IMET=IMET1                                              STB04430
      IF(L.EQ.2)IMET=IMET2                                              STB04440
      WRITE(6,1000)                                                     STB04450
      WRITE(6,10)THSFC(K),THSFC(M),IMET                                 STB04460
   10 FORMAT(3X,'STATIC STABILITY(DEG K/MB) FOR THETA SURFACES ',F6.1,   STB04470
     1' AND ',F6.1,' FOR TIME=',I4,////)                                STB04480
      DO 15 J=1,NJ                                                      STB04490
   15 WRITE(6,20) (STAB(I,NJ-J+1,L),I=1,NI)                             STB04500
   20 FORMAT(2X,11F10.3,///////)                                        STB04510
   30 CONTINUE                                                          STB04520
C                                                                       STB04530
      RETURN                                                            STB04540
      END                                                               STB04550
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      SUBROUTINE MOIST                                                  MSTC4560
C****                                                                   MST04570
C     THIS SUBROUTINE COMPUTES MOISTURE TERMS TO BE USED IN THE MODEL.  MSTC4580
C****                                                                   MST04590
C                                                                       MST04600
      REAL*8 ITITL1                                                     MSTC4610
      REAL*8 ITITL2                                                     MSTC4620
      COMMON ITITL1(12),ITITL2(12),DD(11,9,2,2),FF(11,9,2,2),F(9),DX(9),MST04630
     1PSIM(11,9,2,2),U(11,9,2,12),V(11,9,2,12),UO(11,9,2),VO(11,9,2),   MST04640
     2DMDT1(11,9,2),DMDT2(11,9,2),THSFC(2),UI(12),VI(12),DMDT(12),ALAT  MST04650
     3(12),ALONG(12),DY,SOULAT,WELONG,NI,NJ,NK,NL,IDATE,DELLAT,DT,DELONGMST04660
     4,ANJ,UI2,VI2,NNK,NNI,NNJ,AI,AJ,AK,SUMXD,SUMYD,SDMDT1,YD,XD,NLDAY, MST04670
     5AAI,AAJ,ALATO,ALONGO,IINC,JINC,AIINC,AJINC,XDIST,YDIST,AAII,AAJJ, MST0468C
     6II,JJ,FINALM,AMINIT,AKINIT,FINALK,DELTAM,I,J,K,L,IZ,JZ,Z1(12),PSATMST0469C
     7,PINIT,PFINAL,OMEGA,P(11,9,2,2),VINIT,VFINAL,ACCEL,IMET1,IMET2    MST04700
     8,COUNT,X(12),Y(12),MODCUR,SHDEF(11,9,2,2),STAB(11,9,2),ZO(11,9,2),MSTC4710
     9DIV(11,9,2,2),STDEF(11,9,2,2),VORT(11,9,2,2),AVORT(11,9,2,2),ENGITMST04720
     *,SPD(2),CRS(2),SMU(2),SMV(2),QS(11,9,2,2),QSINIT,QFINL,QSFINL,    MSTC4730
     1RH(11,9,2,2),Q(11,9,2,2),VOFINL,DFINL,VOINT,DINIT,DIFF,QINIT,     MST04740
     2T(11,9,2,2),TD(11,9,2,2),E(11,9,2,2),ES(11,9,2,2),Z(11,9,2,12)    MST0475C
     3,STABI,STABF,PVORTI,PVORTF,POTDIF,QDIF                            MST04751
C                                                                       MST04760
      DO 5 L=1,NL                                                       MST04770
      DO 5 K=1,NK                                                       MST04780
      DO 5 I=1,NI                                                       MST04790
      DO 5 J=1,NJ                                                       MST04800
      RH(I,J,K,L) = RH(I,J,K,L)/100.0                                   MST04810
C****                                                                   MST04820
C     COMPUTE TEMPERATURE(DEGS C) AT EACH GRID POINT.                   MST04830
C****                                                                   MST04840
      DEN = (1000.0/P(I,J,K,L))**0.286                                  MST0485C
      T(I,J,K,L) = (THSFC(K)/DEN) - 273.16                              MST04860
C****                                                                   MST04870
C     COMPUTE DEW POINT TEMPERATURE AT EACH GRID POINT.(DEGS C)         MST04880
C****                                                                   MST04890
      B = 1.0 -RH(I,J,K,L)                                              MST04900
      PP1 = (B**7)*(16.65+.118*T(I,J,K,L))                              MSTC4910
      PP2 = (B**2)*((3.14+.0246*T(I,J,K,L))**2)                         MST04920
      PP3 = B*(13.4+.103*T(I,J,K,L))                                    MST04930
      TD(I,J,K,L) = T(I,J,K,L) - (PP1 + PP2 + PP3)                      MSTC4940
C****                                                                   MST04950
C     COMPUTE VAPOR PRESSURE AT EACH GRID POINT (MB)                    MST496 0
C****                                                                   MST04970
      C = (7.5*TD(I,J,K,L))/(237.3+TD(I,J,K,L))                        MST04980
      E(I,J,K,L) = 6.11*(10**C)                                         MST04990
C****                                                                   MST05000
C     COMPUTE SPECIFIC HUMIDITY AT EACH GRID POINT(GM/GM)               MST05010
C****                                                                   MST05020
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      Q(I,J,K,L) = (0.622*E(I,J,K,L))/(P(I,J,K,L)-0.378*E(I,J,K,L))      MST05030
C****                                                                    MST05040
C     COMPUTE SATURATION VAPOR PRESSURE AT EACH GRID POINT(MB)           MST05050
C****                                                                    MST05060
      ES(I,J,K,L) = E(I,J,K,L)/RH(I,J,K,L)                               MST05070
C****                                                                    MST05080
C     COMPUTE SPECIFIC HUMIDITY AT SATURATION AT EACH GRID POINT( GM/GM)MST05090
C****                                                                    MST05100
      QS(I,J,K,L) = (0.622*ES(I,J,K,L))/(P(I,J,K,L)-0.378*ES(I,J,K,L))   MST05110
C****                                                                    MST05120
C     CONVERT RE. HUMIDITY BACK TC % BEFORE WRITE OUT.                   MST05130
C****                                                                    MST05140
      RH(I,J,K,L) = RH(I,J,K,L)*100.0                                    MST05150
C****                                                                    MST05160
C     COMPUTE MIXING RATIO                                               MST05170
C****                                                                    MST05180
      BIXR = (0.622*E(I,J,K,L))/(P(I,J,K,L)-E(I,J,K,L))                  MST05190
C****                                                                    MST05200
C     COMPUTE VIRTUAL TEMPERATURE                                        MST05210
C****                                                                    MST05230
      TV = (T(I,J,K,L) + 273.16)*(1.0 + 0.61*BIXR)                       MST05240
C****                                                                    MST05250
C     DATA FOR THIS CASE STUDY WAS OBTAINED FCR MONT. STREAM FUNC.       MST05260
C     FROM THE FORMULA M=CP*TV + G*Z, THUS IT WAS NECESSARY TO           MST05270
C     COMPUTE THE VIRTUAL TEMP. NOW OBTAIN THE HEIGHT(Z) IN METERS.      MST05280
C****                                                                    MST05290
      Z(I,J,K,L) = ((PSIM(I,J,K,L) - 1.004*TV)/9.797455)*1000.           MST05300
    5 CONTINUE                                                           MST05310
C****                                                                    MST05320
C     WRITE OUT THE FIELDS COMPUTED                                      MST05330
C****                                                                    MST05340
      DO 90 L=1,NL                                                       MST05350
      DO 90 K=1,NK                                                       MST05360
      IF(L.EQ.1)IMET = IMET1                                             MST05370
      IF(L.EQ.2)IMET = IMET2                                             MST05380
      WRITE(6,1000)                                                      MST05390
 1000 FORMAT(1H1)                                                        MST05400
      WRITE(6,50)IMET,THSFC(K),IDATE                                     MST05410
   50 FORMAT(3X,'RELATIVE HUMIDITY(%) FOR TIME =',I4,' AND FOR THETA =',MST05420
     1F7.1,' DATE =',I6,////)                                            MST05430
      DO 71 J=1,NJ                                                       MST05440
   71 WRITE(6,70) (RH(I,NJ-J+1,K,L),I=1,NI)                              MST05450
   70 FORMAT(2X,11F10.3,////////)                                        MST05460
C                                                                        MST05470
      WRITE(6,1000)                                                      MST05480
      WRITE(6,51)IMET,THSFC(K),IDATE                                     MST05490
   51 FORMAT(3X,'TEMPERATURE(DEGREES CENTIGRADE) FOR TIME =',I4,' AND FOMST05500
     1R THETA =',F7.1,' DATE =',I6,////)                                 MST05510
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      DO 72 J=1,NJ                                                      MST05520
   72 WRITE(6,70) (T(I,NJ-J+1,K,L),I=1,NI)                              MST05530
C                                                                       MST05540
      WRITE(6,1000)                                                     MST05560
      WRITE(6,52)IMET,THSFC(K),IDATE                                    MST05570
   52 FORMAT(3X,'DEWPOINT TEMPERATURE(DEGREES CENTIGRADE) FOR TIME =',I4MST05580
     1,' AND FOR THETA =',F7.1,' DATE =',I6,////)                       MST05590
      DO 73 J=1,NJ                                                      MST05600
   73 WRITE(6,70) (TD(I,NJ-J+1,K,L),I=1,NI)                             MST05610
C                                                                       MST05620
      WRITE(6,1000)                                                     MST05630
      WRITE(6,53)IMET,THSFC(K),IDATE                                    MST05640
   53 FORMAT(3X,'VAPOR PRESSURE(MB) FOR TIME =',I4,' AND FOR THETA =',  MST05650
     1F7.1,' DATE =',I6,////)                                           MST05660
      DO 74 J=1,NJ                                                      MST05670
   74 WRITE(6,70) (E(I,NJ-J+1,K,L),I=1,NI)                              MST05680
C                                                                       MST05690
      WRITE(6,1000)                                                     MST05700
      WRITE(6,54)IMET,THSFC(K),IDATE                                    MST05710
   54 FORMAT(3X'SPECIFIC HUMIDITY(GM/GM) FOR TIME =',I4,' AND FOR THETA MST05720
     1=',F7.1,' DATE =',I6,////)                                        MST05730
      DO 75 J=1,NJ                                                      MST05740
   75 WRITE(6,80) (Q(I,NJ-J+1,K,L),I=1,NI)                              MST05750
   80 FORMAT(2X,11F10.4,////////)                                       MST05760
C                                                                       MST05770
      WRITE(6,1000)                                                     MST05780
      WRITE(6,55)IMET,THSFC(K),IDATE                                    MST05790
   55 FORMAT(3X'SAT. VAPOR PRESSURE(MB) FOR TIME =',I4,' AND FOR THETA =MST05800
     1',F7.1,' DATA =',I6,////)                                         MST05810
      DO 76 J=1,NJ                                                      MST05820
   76 WRITE(6,70) (ES(I,NJ-J+1,K,L),I=1,NI)                             MST05830
C                                                                       MST05840
      WRITE(6,1000)                                                     MST05850
      WRITE(6,56)IMET,THSFC(K),IDATE                                    MST05860
   56 FORMAT(3X'SAT. SPECIFIC HUMIDITY(GM/GM) FOR TIME =',I4,' AND FOR TMST05870
     1HETA =',F7.1,' DATE =',I6,////)                                   MST05880
      DO 77 J=1,NJ                                                      MST05890
   77 WRITE(6,80) (QS(I,NJ-J+1,K,L),I=1,NI)                             MST05900
C                                                                       MST05910
      WRITE(6,1000)                                                     MST05920
      WRITE(6,85)IMET,THSFC(K),IDATE                                    MST05930
   85 FORMAT(3X,'HEIGHT(METERS) FOR TIME =',I4,' AND FOR THETA ='F7.1,   MST05940
     1' DATE =',I6,////)                                                MST05950
      DO 86 J=1,NJ                                                      MST05960
   86 WRITE(6,70) (Z(I,NJ-J+1,K,L),I=1,NI)                              MST05970
C                                                                       MST05980
   90 CONTINUE                                                          MST05990
C                                                                       MST06000
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      RETURN                                                                    MST06010
      END                                                                       MST06020


      SUBROUTINE INTERP                                                         INT06030
C****                                                                           INT06040
C     THIS SUBROUTINE INTERPOLATES U,V AND DMDT AT 7.5 MINUTE INTERVALS         INT06050
C****                                                                           INT06060
      REAL*8 ITITL1                                                             INT06070
      REAL*8 ITITL2                                                             INT06080
C                                                                               INT06090
      COMMON ITITL1(12),ITITL2(12),DD(11,9,2,2),FF(11,9,2,2),F(9),DX(9),INT06100
     1PSIM(11,9,2,2),U(11,9,2,12),V(11,9,2,12),UO(11,9,2),VO(11,9,2),   INT06110
     2DMDT1(11,9,2),DMDT2(11,9,2),THSFC(2),U1(12),V1(12),DMDT(12),ALAT  INT06120
     3(12),ALONG(12),DY,SOULAT,WELONG,NI,NJ,NK,NL,IDATE,DELLAT,DT,DELONGINT06130
     4,ANJ,U12,V12,NNK,NNI,NNJ,AI,AJ,AK,SUMXD,SUMYD,SDMDT1,YD,XD,NLDAY,  INT06140
     5AAI,AAJ,ALATO,ALONGO,IINC,JINC,AIINC,AJINC,XDIST,YDIST,AAII,AAJJ,  INT06150
     6II,JJ,FINALM,AMINIT,AKINIT,FINALK,DELTAM,I,J,K,L,IZ,JZ,Z1(12),PSATINT06170
     7,PINIT,PFINAL,OMEGA,P(11,9,2,2),VINIT,VFINAL,ACCEL,IMET1,IMET2    INT06180
     8,COUNT,X(12),Y(12),MODCUR,SHDEF(11,9,2,2),STAB(11,9,2),ZO(11,9,2),INT06190
     9DIV(11,9,2,2),STDEF(11,9,2,2),VORT(11,9,2,2),AVORT(11,9,2,2),ENGITINT06200
     *,SPD(2),CRS(2),SMU(2),SMV(2),QS(11,9,2,2),QSINIT,QFINL,QSFINL,    INT06210
     1RH(11,9,2,2),Q(11,9,2,2),VOFINL,DFINL,VOINT,DINIT,DIFF,QINIT,     INT06220
     2T(11,9,2,2),TD(11,9,2,2),E(11,9,2,2),ES(11,9,2,2),Z(11,9,2,12)    INT06230
     3,STABI,STABF,PVORTI,PVORTF,POTDIF,QDIF                            INT06231
C                                                                               INT06240
      DO 5 K=1,NK                                                               INT06250
      DO 5 J=1,NJ                                                               INT06260
      DO 5 I=1,NI                                                               INT06270
      DMDT1(I,J,K) = PSIM(I,J,K,2) - PSIM(I,J,K,1)                              INT06280
      IF(NL.EQ.2) GO TO 5                                                       INT06290
    1 DMDT2(I,J,K) = PSIM(I,J,K,3) - PSIM(I,J,K,2)                              INT06300
    5 CONTINUE                                                                  INT06310
C****                                                                           INT06320
C     COMPUTE U AND V AT 7.5 MIN INTERVALS                                      INT06330
C****                                                                           INT06340
      DO 6 K=1,NK                                                               INT06350
      DO 6 J=1,NJ                                                               INT06360
      DO 6 I=1,NI                                                               INT06370
      UO(I,J,K)=U(I,J,K,1)                                                      INT06380
      U12 = U(I,J,K,2)                                                          INT06390
      U(I,J,K,1) = (11./12.)*UO(I,J,K) + (01./12.)*U12                          INT06400
      U(I,J,K,2) = (10./12.)*UO(I,J,K) + (02./12.)*U12                          INT06410
      U(I,J,K,3) = (09./12.)*UO(I,J,K) + (03./12.)*U12                          INT06420
      U(I,J,K,4) = (08./12.)*UO(I,J,K) + (04./12.)*U12                          INT06430
      U(I,J,K,5) = (07./12.)*UO(I,J,K) + (05./12.)*U12                          INT06450
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```
      U(I,J,K,6) = (06./12.)*UO(I,J,K) + (06./12.)*U12                  INT06460
      U(I,J,K,7) = (05./12.)*UO(I,J,K) + (07./12.)*U12                  INT06470
      U(I,J,K,8) = (04./12.)*UO(I,J,K) + (08./12.)*U12                  INT06480
      U(I,J,K,9) = (03./12.)*UO(I,J,K) + (09./12.)*U12                  INT06490
      U(I,J,K,10)= (02./12.)*UO(I,J,K) + (10./12.)*U12                  INT06500
      U(I,J,K,11)= (01./12.)*UO(I,J,K) + (11./12.)*U12                  INT06510
      U(I,J,K,12)=U12                                                   INT06520
C                                                                       INT06530
      VO(I,J,K)=V(I,J,K,1)                                              INT06540
      V12=V(I,J,K,2)                                                    INT06550
      V(I,J,K,1) = (11./12.)*VO(I,J,K) + (01./12.)*V12                  INT06560
      V(I,J,K,2) = (10./12.)*VO(I,J,K) + (02./12.)*V12                  INT06570
      V(I,J,K,3) = (09./12.)*VO(I,J,K) + (03./12.)*V12                  INT06580
      V(I,J,K,4) = (08./12.)*VO(I,J,K) + (04./12.)*V12                  INT06590
      V(I,J,K,5) = (07./12.)*VO(I,J,K) + (05./12.)*V12                  INT06600
      V(I,J,K,6) = (06./12.)*VO(I,J,K) + (06./12.)*V12                  INT06610
      V(I,J,K,7) = (05./12.)*VO(I,J,K) + (07./12.)*V12                  INT06620
      V(I,J,K,8) = (04./12.)*VO(I,J,K) + (08./12.)*V12                  INT06630
      V(I,J,K,9) = (03./12.)*VO(I,J,K) + (09./12.)*V12                  INT06640
      V(I,J,K,10)= (02./12.)*VO(I,J,K) + (10./12.)*V12                  INT06650
      V(I,J,K,11)= (01./12.)*VO(I,J,K) + (11./12.)*V12                  INT06660
      V(I,J,K,12)= V12                                                  INT06670
C                                                                       INT06680
      ZO(I,J,K)=Z(I,J,K,1)                                              INT06690
      Z12 = Z(I,J,K,2)                                                  INT06700
      Z(I,J,K,1) = (11./12.)*ZO(I,J,K) + (01./12.)*Z12                  INT06710
      Z(I,J,K,2) = (10./12.)*ZO(I,J,K) + (02./12.)*Z12                  INT06720
      Z(I,J,K,3) = (09./12.)*ZO(I,J,K) + (03./12.)*Z12                  INT06730
      Z(I,J,K,4) = (08./12.)*ZO(I,J,K) + (04./12.)*Z12                  INT06740
      Z(I,J,K,5) = (07./12.)*ZO(I,J,K) + (05./12.)*Z12                  INT06750
      Z(I,J,K,6) = (06./12.)*ZO(I,J,K) + (06./12.)*Z12                  INT06760
      Z(I,J,K,7) = (05./12.)*ZO(I,J,K) + (07./12.)*Z12                  INT06770
      Z(I,J,K,8) = (04./12.)*ZO(I,J,K) + (08./12.)*Z12                  INT06780
      Z(I,J,K,9) = (03./12.)*ZO(I,J,K) + (09./12.)*Z12                  INT06790
      Z(I,J,K,10) = (02./12.)*ZO(I,J,K) + (10./12.)*Z12                 INT06800
      Z(I,J,K,11) = (01./12.)*ZO(I,J,K) + (11./12.)*Z12                 INT06810
      Z(I,J,K,12) = Z12                                                 INT06820
C                                                                       INT06830
    6 CONTINUE                                                          INT06840
C                                                                       INT06850
C****                                                                   INT06860
C     WRITE OUT U AND V COMPONENT FIELDS                                INT06870
C****                                                                   INT06880
      WRITE(6,1000)                                                     INT06890
 1000 FORMAT(1H1)                                                       INT06900
      DO 7 L=1,12                                                       INT06910
      DO 7 K=1,NK                                                       INT06920
      WRITE(6,9) L,THSFC(K)                                             INT06930
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      DO 7 J=1,NJ                                                       INT06940
    7 WRITE(6,10) (U(I,NJ-J+1,K,L),I=1,NI)                              INTC6950
    9 FORMAT(2X,'U COMPONENT OF WIND AT L = 'I2,'THETA=',F6.1,//)       INTC6960
   10 FORMAT(2X,11F8.2,//)                                              INTC6970
      DO 8 L=1,12                                                       INTC6980
      DO 8 K=1,NK                                                       INTC6990
      WRITE(6,11) L,THSFC(K)                                            INT07000
      DO 8 J=1,NJ                                                       INTC7010
    8 WRITE(6,10) (V(I,NJ-J+1,K,L),I=1,NI)                              INTC7020
   11 FORMAT(2X,'V COMPONENT OF WIND AT L = ',I2,'THETA=',F6.1,//)       INT07030
C                                                                       INT07040
      DO 20 L=1,12                                                      INT07050
      DO 20 K=1,NK                                                      INTC7060
      WRITE(6,21) L,THSFC(K)                                            INT07070
      DO 20 J=1,NJ                                                      INT07080
   21 FORMAT(2X,'HEIGHT(M) AT L= ',I2,'THETA=',F6.1,//)                 INT07090
   20 WRITE(6,22) (Z(I,NJ-J+1,K,L),I=1,NI)                              INTC7100
   22 FORMAT(2X,11F8.2,//)                                              INT07110
C****                                                                   INT07120
C     ABOVE ROUTINE ASSUMES NL = 2                                      INT07130
C****                                                                   INT07140
      RETURN                                                            INT07150
      END                                                               INT07160


      SUBRCUTINE TRAJ                                                   TRJ07170
C****                                                                   TRJ07180
C     THIS SUBROUTINE EVALUATES FIRST GUESS TRAJECTORY WITHOUT ENERGY   TRJ07190
C     INTEGRAL CORRECTION                                               TRJ07200
C****                                                                   TRJC7210
      REAL*8 ITITL1                                                     TRJ07220
      REAL*8 ITITL2                                                     TRJC7230
      REAL*4 LABEL/4H    /                                              TRJ07240
C                                                                       TRJ07250
      COMMON ITITL1(12),ITITL2(12),DD(11,9,2,2),FF(11,9,2,2),F(9),DX(9),TRJ07260
     1PSIM(11,9,2,2),U(11,9,2,12),V(11,9,2,12),UO(11,9,2),VO(11,9,2),   TRJ07270
     2DMDT1(11,9,2),DMDT2(11,9,2),THSFC(2),U1(12),V1(12),DMDT(12),ALAT  TRJ07280
     3(12),ALONG(12),DY,SOULAT,WELONG,NI,NJ,NK,NL,IDATE,DELLAT,DT,DELONGTRJC7290
     4,ANJ,U12,V12,NNK,NNI,NNJ,AI,AJ,AK,SUMXD,SUMYD,SDMDT1,YD,XD,NLDAY, TRJ07300
     5AAI,AAJ,ALATC,ALONGC,IINC,JINC,AIINC,AJINC,XDIST,YDIST,AAII,AAJJ, TRJ07310
     6II,JJ,FINALM,AMINIT,AKINIT,FINALK,DELTAM,I,J,K,L,IZ,JZ,Z1(12),PSATTRJ07320
     7,PINIT,PFINAL,OMEGA,P(11,9,2,2),VINIT,VFINAL,ACCEL,IMET1,IMET2    TRJ07330
     8,COUNT,X(12),Y(12),MODCUR,SHDEF(11,9,2,2),STAB(11,9,2),ZO(11,9,2),TRJC7340
     9DIV(11,9,2,2),STDEF(11,9,2,2),VORT(11,9,2,2),AVCRT(11,9,2,2),ENGITTRJ07350
     *,SPD(2),CRS(2),SMU(2),SMV(2),QS(11,9,2,2),QSINIT,QFINL,QSFINL,    TRJ07360
     1RH(11,9,2,2),Q(11,9,2,2),VOFINL,DFINL,VCINT,DINIT,DIFF,QINIT,     TRJ07370
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     2T(11,9,2,2),TD(11,9,2,2),E(11,9,2,2),ES(11,9,2,2),Z(11,9,2,12)     TRJ07380
     3,STABI,STABF,PVORTI,PVORTF,POTDIF,QDIF                             TRJ07381
C                                                                        TRJ07390
 1000 FORMAT(1H1)                                                        TRJ07400
C****                                                                    TRJ07410
C       SET 85 % DIFFERENCE BETWEEN SPECIFIC HUMIDITY AND SATURATED      TRJ07420
C       SPECIFIC HUMIDITY                                                TRJ07430
C****                                                                    TRJ07440
       ALFAQ = 0.85                                                      TRJ07450
       NNK=NK-1                                                          TRJ07460
       NNI=NI-1                                                          TRJ07470
       NNJ=NJ-1                                                          TRJ07480
     5 DO 99 K=1,NK                                                      TRJ07490
C****                                                                    TRJ07500
C       COUNTER FOR GRAPHIC DISPLAY                                      TRJ07510
C****                                                                    TRJ07520
       COUNT =1                                                          TRJ07530
       DO 99 J=2,NNJ                                                     TRJ07540
       DO 99 I=2,NNI                                                     TRJ07550
       AI=I                                                              TRJ07560
       AJ=J                                                              TRJ07570
       AK=K                                                              TRJ07580
       SUMXD=0.0                                                         TRJ07590
       SUMYD=0.0                                                         TRJ07600
       IZ=I                                                              TRJ07610
       JZ = J                                                            TRJ07620
       SDMDT1=0.0                                                        TRJ07630
C****                                                                    TRJ07640
C       BEGIN LOOP TO EVALUATE FIRST 1.5 HOUR TRAJECTORIES               TRJ07650
C       COMPUTE INITIAL DISPLACEMENT IN METERS                           TRJ07660
C****                                                                    TRJ07670
       XD = UO(I,J,K)*450.                                               TRJ07680
       YD = VO(I,J,K)*450.                                               TRJ07690
       NLDAY=(NL-1)*12                                                   TRJ07700
       AAI=AI                                                            TRJ07710
       AAJ=AJ                                                            TRJ07720
       ALATO = SOULAT + DELLAT*(AAJ -1.)                                 TRJ07730
       ALONGO = WELONG - DELONG*(AAI - 1.)                               TRJ07740
C                                                                        TRJ07750
       WRITE(6,1000)                                                     TRJ07760
       WRITE(6,19) ALATO,ALONGO,THSFC(K)                                 TRJ07770
    19 FORMAT(2X,'KINEMATIC TRAJECTORIES AT 7.5 MINS INTERVALS BEGINNING TRJ07780
      1AT LATITUDE = ',F6.2,' AND AT LONGITUDE = ',F7.2,' FOR THETA = ', TRJ07790
      2F6.1,//)                                                          TRJ07800
       WRITE(6,20)                                                       TRJ07810
    20 FORMAT(3X,'TIME STEP',5X,'LATITUDE',5X,'LONGITUDE',6X,'U',11X,'V',TRJ07820
      114X,'Z')                                                          TRJ07830
       WRITE(6,21) ALATO,ALONGO,UO(I,J,K),VO(I,J,K),ZO(I,J,K)           TRJ07840
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   21 FORMAT(10X,'0',7X,F5.2,7X,F6.2,6X,F6.1,6X,F6.1,9X,F8.2)                TRJ07850
C****                                                                       TRJ07860
C      BEGIN DO LOOP TO COMPUTE AND PRINTOUT KINEMATIC TRAJECTORIES         TRJ07870
C****                                                                       TRJ07880
       L=1                                                                  TRJ07890
C****                                                                       TRJ07900
C      COMPUTE INITIAL VALUES FOR VARIOUS PARAMETERS ON THE TRAJECTORY.     TRJ07910
C      TEMP.,SPECIFIC HUMIDITY,SAT.SPECIFIC HUMIDITY,VORTICITY,DIVERGENCE  TRJ07920
C      WIND VELOCITY,PRESSURE,MONT.STREAM FUNC., KINETIC ENERGY             TRJ07930
C      STATIC STABILITY AND POTENTIAL VORTICITY.                            TRJ07931
C****                                                                       TRJ07940
       TINIT = T(I,J,K,L) + 273.16                                          TRJ07950
       QINIT = Q(I,J,K,L)                                                   TRJ07960
       QSINIT = QS(I,J,K,L)                                                 TRJ07970
       VOINT = AVORT(I,J,K,L)                                               TRJ07980
       DINIT = DIV(I,J,K,L)                                                 TRJ07990
       VINIT = FF(I,J,K,L)                                                  TRJ08000
       PINIT = P(I,J,K,L)                                                   TRJ08010
       AMINIT = PSIM(I,J,K,L)                                               TRJ08020
       AKINIT = .5*(FF(I,J,K,L))**2                                         TRJ08030
       STABI = STAB(I,J,L)                                                  TRJ08031
       PVORTI = STABI*VOINT*1000.0                                          TRJ08032
       DO 98 L=1,NLDAY                                                      TRJ08040
       SUMXD=SUMXD+XD                                                       TRJ08050
       SUMYD=SUMYD+YD                                                       TRJ08060
C****                                                                       TRJ08070
C      AIINC AND AJINC ARE THE NUMBER OF GRID POINTS THE TRAJECTORIES ARE   TRJ08080
C      DISPLACED FROM THE ORIGINAL I,J GRID POINT                           TRJ08090
C****                                                                       TRJ08100
       AIINC = 2.*SUMXD/(DX(J) + DX(JZ))                                    TRJ08110
       AJINC=SUMYD/DY                                                       TRJ08120
C****                                                                       TRJ08130
C      ROUTINE TO SEE IF TRAJECTORY HAS LEFT THE FIELD                      TRJ08140
C****                                                                       TRJ08150
       ANJ = NJ                                                             TRJ08160
       ANI = NI                                                             TRJ08170
       TESTAI = AAI + AIINC                                                 TRJ08190
       TESTAJ = AAJ + AJINC                                                 TRJ08200
       IZ=TESTAI                                                            TRJ08210
       JZ=TESTAJ                                                            TRJ08220
       IF(TESTAJ .LT. 1.) GO TO 1                                           TRJ08230
       IF(TESTAJ .GT.  ANJ) GO TO 1                                         TRJ08240
       IF(TESTAI .LT. 1.) GO TO 1                                           TRJ08250
       IF(TESTAI .GT. ANI) GO TO 1                                          TRJ08260
C                                                                           TRJ08270
    3  GO TO 4                                                              TRJ08280
    1  WRITE(6,2) IZ,JZ,L                                                   TRJ08290
    2  FORMAT('  TRAJECTORY TERMINATES AT IZ =  ',I3,'  JZ =  ',I3,'  ANDTRJ08300
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     1 AT L =  ',I3)                                                          TRJ08310
C****                                                                         TRJ08320
C       THE NEXT CARDS ARE FOR THE CALL DRAW STATEMENT ROUTINE TO PRINT       TRJ08330
C       OUT THE TRAJECTORIES THAT ARE LESS THAN 12 POINTS. ICK IS JUST        TRJ08340
C       NAME CF CCUNTER TO KEEP TRACK PROGRAM POSITION. SINCE NUMBER OF       TRJ08350
C       POINTS TO PLOT FOR CURVE IS ONE LESS THAN L COUNTER MUST SUBT. 1.     TRJ08360
C****                                                                         TRJ08370
        L = L - 1                                                             TRJ08380
        ICK = 5                                                               TRJC8390
        GO TO 49                                                              TRJ08400
  300   GO TO 99                                                              TRJ08410
    4   CONTINUE                                                              TRJC8420
C****                                                                         TRJ08430
C       XDIST AND YDIST ARE THE DISTANCES CF THE TRAJECTORY POINT FROM THETRJ08440
C       NEW GRID POINTS IINC AND JINC                                         TRJ08450
C****                                                                         TRJ08460
        XDIST = (TESTAI - IZ)*DX(JZ)                                          TRJ08470
        YDIST = (TESTAJ - JZ)*DY                                              TRJC8480
C****                                                                         TRJC8490
C       FIND NEW WINC SPEEDS AT END POINT BY INTERPCLATION ROUTINE TO FINDTRJ08500
C       GRID POINTS SURROUNDING TRAJECTORY POINT                              TRJ08510
C****                                                                         TRJ08520
        IF(XDIST .GE. 0. .AND. YDIST .GE. 0.) GO TO 45                        TRJ08530
        IF(XDIST .GE. 0. .AND. YDIST .LT. 0.) GO TO 41                        TRJ08540
        IF(XDIST .LT. 0. .AND. YDIST .GE. 0.) GO TO 42                        TRJ08550
        IF(XDIST .LT. 0. .AND. YDIST .LT. 0.) GO TO 43                        TRJ08560
C****                                                                         TRJ08570
C       ROUTINE TO PUT THE NEW I AND J PCINTS AT THE LOWER LEFT HAND CORNETRJ08580
C       OF BOX SURROUNDING THE TRAJECTORY POINT                               TRJ08590
C****                                                                         TRJ08600
   41   JZ = JZ - 1                                                           TRJ08610
        YDIST = DY + YDIST                                                    TRJC8620
        GO TO 45                                                              TRJ08630
C                                                                             TRJ08640
   42   IZ = IZ - 1                                                           TRJ08650
        XDIST = DX(JZ) + XDIST                                                TRJ08660
        GO TO 45                                                              TRJ08670
C                                                                             TRJ08680
   43   IZ = IZ - 1                                                           TRJC8690
        JZ = JZ - 1                                                           TRJC8700
        YDIST = DY + YDIST                                                    TRJ08710
        XDIST = DX(JZ) + XDIST                                                TRJ08720
C****                                                                         TRJ08730
C       XDIST AND YDIST ARE NOW THE DISTANCES FROM THE LOWER LEFT GRID POITRJ08740
C       COMPUTE U, V AND Z FOR END POINT OF TRAJECTORY                        TRJ08750
C****                                                                         TRJC8760
   45   U1(L)=U(IZ,JZ,K,L) + (U(IZ+1,JZ,K,L) - U(IZ,JZ,K,L))*(XDIST/DX(JZ)TRJ08770
     1) + ((U(IZ,JZ+1,K,L) - U(IZ,JZ,K,L))*(DX(JZ)-XDIST)/(DY*DX(JZ)) + TRJ08780
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     2 (U(IZ+1,JZ+1,K,L) - U(IZ+1,JZ,K,L))*(XDIST/(DY*DX(JZ))))*YDIST   TRJ08790
C                                                                       TRJ08800
      V1(L) = V(IZ,JZ,K,L) + (V(IZ+1,JZ,K,L) - V(IZ,JZ,K,L))*(XDIST/DX(JTRJC8810
     1Z))+ ((V(IZ,JZ+1,K,L) - V(IZ,JZ,K,L))*(DX(JZ)-XDIST)/(DY*DX(JZ))+ TRJ08820
     2 (V(IZ+1,JZ+1,K,L) - V(IZ+1,JZ,K,L))*(XDIST/(DY*DX(JZ))))*YDIST   TRJ08830
C                                                                       TRJ08840
      Z1(L) = Z(IZ,JZ,K,L) + (Z(IZ+1,JZ,K,L) - Z(IZ,JZ,K,L))*(XDIST/DX(JTRJ08850
     1Z))+ ((Z(IZ,JZ+1,K,L) - Z(IZ,JZ,K,L))*(DX(JZ)-XDIST)/(DY*DX(JZ))+ TRJ08860
     2 (Z(IZ+1,JZ+1,K,L) - Z(IZ+1,JZ,K,L))*(XDIST/(DY*DX(JZ))))*YDIST   TRJ08870
C                                                                       TRJ08880
      DMDT(L) = DMDT1(IZ,JZ,K) + (DMDT1(IZ+1,JZ,K)-DMDT1(IZ,JZ,K))*(XDISTRJC8890
     1T/DX(JZ))   +   ((DMDT1(IZ,JZ+1,K) - DMDT1(IZ,JZ,K))*(DX(JZ) -    TRJ08900
     2XDIST)/(DY*DX(JZ)) + (DMDT1(IZ+1,JZ+1,K) - DMDT1(IZ+1,JZ,K))*(XDISTRJ08910
     3T/(DY*DX(JZ))))*YDIST                                             TRJ08920
C                                                                       TRJC8930
      ALAT(L) = SOULAT + DELLAT*(JZ - 1. + YDIST/DY)                    TRJC8940
      ALONG(L) = WELONG - DELONG*(IZ - 1. + XDIST/DX(JZ))               TRJC8950
C                                                                       TRJ08960
      ICK = 2                                                           TRJC8970
      IF(L.EQ.12) GO TO 49                                              TRJC8980
      GO TO 50                                                          TRJC8990
C****                                                                   TRJ09000
C     THIS ROUTINE IS DESIGNED TO MAKE A PLOT OF THE TRAJECTORIES       TRJ09010
C     USING SUBROUTINE DRAW. IT WILL PLOT ALL TRAJECTORIES.             TRJ09020
C     THE ROUTINE IS GOOD ONLY FOR IBM/360 AT USNPGS                    TRJ09030
C****                                                                   TRJ09040
   49 DO 55 LL=1,L                                                      TRJ09050
      X(LL) = (ALAT(LL)-34.00)*4.                                       TRJ09060
      Y(LL) = (ALONG(LL)-97.00)*4.                                      TRJ09070
   55 CONTINUE                                                          TRJ09080
      IF(CCUNT.EQ.1)MODCUR=1                                            TRJ09090
      IF(CCUNT.GT.1)MODCUR=2                                            TRJ09100
      IF(COUNT.EQ.63)MODCUR=3                                           TRJ09110
      IF(K.EQ.2) GO TO 71                                               TRJ09120
      IF(K.EQ.1) GO TO 70                                               TRJ09130
   70 CALL DRAW(L,X,Y,MODCUR,0,LABEL,ITITL1,1.0,1.0,0,0,2,2,8,10,1,LAST)TRJ09140
      GO TO 72                                                          TRJ09150
   71 CALL DRAW(L,X,Y,MODCUR,0,LABEL,ITITL2,1.0,1.0,0,0,2,2,8,10,1,LAST)TRJ09160
   72 COUNT = COUNT + 1                                                 TRJ09170
      IF(ICK.EQ.5) GO TO 300                                            TRJ09180
   50 CONTINUE                                                          TRJ09190
C                                                                       TRJC9200
      WRITE(6,51) L,ALAT(L),ALONG(L),U1(L),V1(L),Z1(L)                  TRJC9210
   51 FORMAT(08X,I3,7X,F5.2,7X,F6.2,6X,F6.1,6X,F6.1,9X,F8.2)            TRJ09220
      SDMDT1 = SDMDT1 + DMDT(L)                                         TRJ09230
      XD = U1(L)*450.                                                   TRJ09240
      YD = V1(L)*450.                                                   TRJ09250
C                                                                       TRJ09260
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      IF(L .LT. 12) GO TO 98                                                    TRJC9270
C****                                                                           TRJC9280
C     COMPUTE FINAL KINETIC ENERGY                                              TRJ09290
C****                                                                           TRJ09300
      FINALK = .5*(U1(L)**2 + V1(L)**2)                                         TRJC9310
C                                                                               TRJ09320
      DELTAM = SDMDT1/12.                                                       TRJ09330
C****                                                                           TRJ09340
C     COMPUTE FINAL MONT. STREAM FUNC.                                          TRJ09350
C****                                                                           TRJ09360
      FINALM = PSIM(IZ,JZ,K,2) + (PSIM(IZ+1,JZ,K,2)   -                        TRJ09370
     1  PSIM(IZ,JZ,K,2))*(XDIST/DX(JZ)) + ((PSIM(IZ,JZ+1,K,2) -                 TRJ09380
     2 PSIM(IZ,JZ,K,2))*(DX(JZ)-XDIST)/(DY*DX(JZ))+(PSIM(IZ+1,JZ+1,K,2)        TRJ09390
     3 - PSIM(IZ+1,JZ,K,2))*(XDIST/(DY*DX(JZ))))*YDIST                         TRJ09400
C****                                                                           TRJ09410
C     COMPUTE ACCELERATION OF THE AIR PARCEL DURING THE TRAJECTORY              TRJ09420
C****                                                                           TRJ09430
      VFINAL = SQRT(U1(L)**2 + V1(L)**2)                                        TRJ09440
      ACCEL = (VFINAL - VINIT)*2./3.                                            TRJC9450
C****                                                                           TRJC9460
C     COMPUTE FINAL PRESSURE                                                    TRJ09470
C****                                                                           TRJ09480
      PFINAL = P(IZ,JZ,K,2) + (P(IZ+1,JZ,K,2) -                                 TRJ09490
     1 P(IZ,JZ,K,2))*(XDIST/DX(JZ)) + ((P(IZ,JZ+1,K,2) -                        TRJ09500
     2 P(IZ,JZ,K,2))*(DX(JZ)-XDIST)/(DY*DX(JZ)) +(P(IZ+1,JZ+1,K,2)              TRJ09510
     3 - P(IZ+1,JZ,K,2))*(XDIST/(DY*DX(JZ))))*YDIST                            TRJ09520
C****                                                                           TRJ09530
C     COMPUTE VERTICAL MOTION.                                                  TRJ09540
C****                                                                           TRJ09550
      OMEGA = (PFINAL - PINIT)* 2./3.                                           TRJ09560
C****                                                                           TRJ09561
C     COMPUTE FINAL STATIC STABILITY                                            TRJ09562
C****                                                                           TRJ09563
      STABF = STAB(IZ,JZ,2) + (STAB(IZ+1,JZ,2) - STAB(IZ,JZ,2))*(XDIST          TRJ09564
     1/DX(JZ)) + ((STAB(IZ,JZ+1,2) - STAB(IZ,JZ,2))*(DX(JZ)-XDIST)/             TRJ09565
     2(DY*DX(JZ)) + (STAB(IZ+1,JZ+1,2) - STAB(IZ+1,JZ,2))*(XDIST/(DY*           TRJ09566
     3DX(JZ))))*YDIST                                                           TRJ09567
C****                                                                           TRJ09570
C     COMPUTE FINAL SPECIFIC HUMIDITY (GM/GM)                                   TRJ09580
C****                                                                           TRJ09590
      QFINL = Q(IZ,JZ,K,2) + (Q(IZ+1,JZ,K,2) - Q(IZ,JZ,K,2))*(XDIST/DX          TRJ09600
     1(JZ)) + ((Q(IZ,JZ+1,K,2) - Q(IZ,JZ,K,2))*(DX(JZ)-XDIST)/(DY*DX(JZ)TRJ09610
     2) + (Q(IZ+1,JZ+1,K,2) - Q(IZ+1,JZ,K,2))*(XDIST/(DY*DX(JZ))))*YDISTTRJ09620
C****                                                                           TRJ09630
C     COMPUTE FINAL SATURATED SPECIFIC HUMIDITY (GM/GM)                         TRJC9640
C****                                                                           TRJ09650
      QSFINL = QS(IZ,JZ,K,2) + (QS(IZ+1,JZ,K,2) - QS(IZ,JZ,K,2))*(XDIST TRJC966C
     1/DX(JZ)) + ((QS(IZ,JZ+1,K,2) - QS(IZ,JZ,K,2))*(DX(JZ)-XDIST)/(DY* TRJ09670
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     2DX(JZ)) + (QS(IZ+1,JZ+1,K,2) - QS(IZ+1,JZ,K,2))*(XDIST/(DY*DX(JZ)  TRJC9680
     3)))*YDIST                                                          TRJC9690
C****                                                                    TRJC9700
C      COMPUTE FINAL ABSOLUTE VORTICITY                                  TRJ09710
C****                                                                    TRJ09720
      VOFINL = AVORT(IZ,JZ,K,2) + (AVORT(IZ+1,JZ,K,2) - AVORT(IZ,JZ,K,2)TRJ09730
     1)*(XDIST/DX(JZ)) + ((AVORT(IZ,JZ+1,K,2) - AVORT(IZ,JZ,K,2))*(DX(JZTRJ09740
     2)- XDIST)/(DY*DX(JZ)) + (AVORT(IZ+1,JZ+1,K,2) - AVORT(IZ+1,JZ,K,2)TRJ09750
     3)*(XDIST/(DY*DX(JZ))))*YDIST                                       TRJ09760
C****                                                                    TRJC9770
C      COMPUTE FINAL DIVERGENCE                                          TRJ09780
C****                                                                    TRJC9790
      DFINL = DIV(IZ,JZ,K,2) + (DIV(IZ+1,JZ,K,2) - DIV(IZ,JZ,K,2))*     TRJ09800
     1(XDIST/DX(JZ)) + ((DIV(IZ,JZ+1,K,2) - DIV(IZ,JZ,K,2))*(DX(JZ)-    TRJC9810
     2XDIST)/(DY*DX(JZ)) + (DIV(IZ+1,JZ+1,K,2) - DIV(IZ+1,JZ,K,2))*     TRJ09820
     3(XDIST/(DY*DX(JZ))))*YDIST                                         TRJ09830
C****                                                                    TRJ09831
C      COMPUTE FINAL POTENTIAL VORTICITY                                 TRJ09832
C****                                                                    TRJ09833
      PVORTF = STABF*VOFINL*1000.0                                       TRJ09834
C****                                                                    TRJ09840
C      COMPUTE FOR EACH POINT THE PRESSURE THE PARCEL MUST BE LIFTED     TRJC9850
C      IN ORDER TO BECOME SATURATED                                      TRJ09860
C****                                                                    TRJC9870
      DQS = QINIT - ALFAQ*QSINIT                                         TRJ09880
      BOT = QSINIT*((1548.84/TINIT) - 1.0)                               TRJ09890
      PSAT = PINIT*(1.0 + DQS/BOT)                                       TRJ09900
C****                                                                    TRJC9910
C      COMPUTE TIME OF SATURATION                                        TRJ09920
C****                                                                    TRJC9930
      TIMSAT = ((PSAT-PINIT)/(PFINAL-PINIT))*1.5                         TRJC9940
C****                                                                    TRJ09950
C      COMPUTE INITIAL TOTAL ENERGY FOR AIR PARCEL (10**7 ERG/GM)        TRJ09960
C****                                                                    TRJ09970
      ENGIT = AMINIT + 1111.48*QINIT + AKINIT/1000.                      TRJC9980
C****                                                                    TRJC9990
C      COMPUTE FINAL TOTAL ENERGY FOR AIR PARCEL (10**7 ERG/GM)          TRJ10000
C****                                                                    TRJ10010
      ENGFL = FINALM + 1111.48*QFINL + FINALK/1000.                      TRJ10020
C****                                                                    TRJ10030
C      COMPUTE CHANGE IN ENERGY                                          TRJ10040
C****                                                                    TRJ10050
      ENGDIF = ENGFL - ENGIT                                             TRJ10060
C****                                                                    TRJ10070
C      COMPUTE CHANGE IN VORTICITY                                       TRJ10080
C****                                                                    TRJ10090
      VORDIF = VOFINL - VOINT                                            TRJ10100
C****                                                                    TRJ10101
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C      COMPUTE CHANGE IN SPECIFIC HUMIDITY                                    TRJ10102
C****                                                                         TRJ10103
       QDIF = QFINL - QINIT                                                   TRJ10104
C****                                                                         TRJ10110
C      COMPUTE CHANGE IN DIVERGENCE                                           TRJ10120
C****                                                                         TRJ10130
       DIVDIF = DFINL - DINIT                                                 TRJ10140
C****                                                                         TRJ10141
C      COMPUTE CHANGE IN POTENTIAL VORTICITY                                  TRJ10142
C****                                                                         TRJ10143
       POTDIF = PVORTF - PVORTI                                               TRJ10144
C                                                                             TRJ10150
       WRITE(6,80) PINIT,PFINAL,OMEGA,ACCEL                                   TRJ10160
    80 FORMAT(//,2X,'INITIAL P =',F5.1,',FINAL P =',F5.1,',OMEGA(MB/HR)       TRJ10170
      1=',F5.1,', ACCELERATION(M/SEC-HR) =',F5.1,//)                          TRJ10180
C                                                                             TRJ10190
       WRITE(6,81) QINIT,QFINL,QDIF,QSINIT,QSFINL                             TRJ10200
    81 FORMAT(//,2X,' INITIAL Q(GM/GM)= ',F9.4,' FINAL Q= ',F9.4,' CHANGE     TRJ10210
      1= ',F9.4,' INITIAL QS= ',F9.4,' FINAL QS= ',F9.4,//)                   TRJ10220
C                                                                             TRJ10230
       WRITE(6,82) VOINT,VOFINL,VORDIF                                        TRJ10240
    82 FORMAT(//,2X,'INITIAL VORTICITY(10**-4)= ',F9.3,' FINAL VORTICITY     TRJ10250
      1(10**-4)= ',F9.3,2X,'CHANGE=',F9.3,//)                                 TRJ10260
C                                                                             TRJ10270
       WRITE(6,83) DINIT,DFINL,DIVDIF                                         TRJ10280
    83 FORMAT(//,2X,'INITIAL DIVERGENCE(10**-4)= ',F9.3,'FINAL DIVERGENCE     TRJ10290
      1(10**-4)= ',F9.3,2X,'CHANGE=',F9.3,//)                                 TRJ10300
C                                                                             TRJ10310
       WRITE(6,84) AMINIT,FINALM                                              TRJ10320
    84 FORMAT(//,2X,'INITIAL MONT. STR. FUNC. =',F9.3,' FINAL MONT. STR.     TRJ10340
      1FUNC. =',F9.3,//)                                                      TRJ10350
C                                                                             TRJ10360
       WRITE(6,85) AKINIT,FINALK                                              TRJ10370
    85 FORMAT(//,2X,'INITIAL KINETIC ENERGY =',F9.3,' FINAL KINETIC ENERG     TRJ10380
      1Y =',F9.3,//)                                                          TRJ10390
C                                                                             TRJ10400
       WRITE(6,87) PSAT,TIMSAT                                                TRJ10410
    87 FORMAT(//,2X,'SATURATED PRESSURE = ',F8.2,2X,'TIME OF SATURATION       TRJ10420
      1= ',F7.3,//)                                                           TRJ10430
C                                                                             TRJ10440
       WRITE(6,88) ENGIT,ENGFL,ENGDIF                                         TRJ10450
    88 FORMAT(//,2X,'INITIAL ENERGY(10**7 ERG/GM) =',F9.3,2X,'FINAL ENERG     TRJ10460
      1Y =',F9.3,2X,'CHANGE =',F9.3,//)                                       TRJ10470
C                                                                             TRJ10480
       WRITE(6,89) STABI,STABF                                                TRJ10481
    89 FORMAT(//,2X,'INITIAL STABILITY= ',F9.3,' FINAL STABILITY= ',          TRJ10482
      1F9.3,//)                                                               TRJ10483
C                                                                             TRJ10484
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      WRITE(6,90) PVORTI,PVORTF,POTDIF                                  TRJ10485
   90 FORMAT(//,2X,'INITIAL POT. VORT.(10**-10 DEG. K SEC CM/GM)= ',    TRJ10486
     1F9.3,' FINAL POT. VORT.= ', F9.3,' CHANGE= ',F9.3,//)             TRJ10487
C                                                                       TRJ10488
      WRITE(6,86) LAST                                                  TRJ10490
   86 FORMAT(//,2X,'LAST =',I2,//)                                      TRJ10500
   98 CONTINUE                                                          TRJ10510
C****                                                                   TRJ10520
C     IF IT IS DESIRED TO ADJUST THE KINEMATIC TRAJECTORIES FROM THE    TRJ10530
C     TOTAL ENERGY EQUATION, "CALL ENERGY" WOULD BE INSERTED AT THIS    TRJ10540
C     POINT.                                                            TRJ10550
C****                                                                   TRJ10560
   99 CONTINUE                                                          TRJ10580
C                                                                       TRJ10590
C                                                                       TRJ10600
      RETURN                                                            TRJ10610
      END                                                               TRJ10620


      SUBROUTINE ENERGY                                                 ENG10630
C****                                                                   ENG10640
C     THIS SUBROUTINE ITERATIVELY ADJUSTS THE KINEMATIC TRAJECTORIES    ENG10650
C     FROM THE TOTAL ENERGY EQUATION EXPRESSED IN ISENTROPIC            ENG10660
C     COORDINATE SYSTEM.                                                ENG10670
C****                                                                   ENG10680
      REAL*8 ITITL1                                                     ENG10690
      REAL*8 ITITL2                                                     ENG10700
C                                                                       ENG10710
      COMMON ITITL1(12),ITITL2(12),DD(11,9,2,2),FF(11,9,2,2),F(9),DX(9),ENG10720
     1PSIM(11,9,2,2),U(11,9,2,12),V(11,9,2,12),UO(11,9,2),VO(11,9,2),   ENG10730
     2DMDT1(11,9,2),DMDT2(11,9,2),THSFC(2),U1(12),V1(12),DMDT(12),ALAT  ENG10740
     3(12),ALONG(12),DY,SCULAT,WELONG,NI,NJ,NK,NL,IDATE,DELLAT,DT,DELONGENG10750
     4,ANJ,U12,V12,NNK,NNI,NNJ,AI,AJ,AK,SUMXD,SUMYD,SDMDT1,YD,XD,NLDAY, ENG10760
     5AAI,AAJ,ALATC,ALONGO,IINC,JINC,AIINC,AJINC,XDIST,YDIST,AAII,AAJJ, ENG10770
     6II,JJ,FINALM,AMINIT,AKINIT,FINALK,DELTAM,I,J,K,L,IZ,JZ,Z1(12),PSATENG10780
     7,PINIT,PFINAL,OMEGA,P(11,9,2,2),VINIT,VFINAL,ACCEL,IMET1,IMET2    ENG10790
     8,COUNT,X(12),Y(12),MODCUR,SHDEF(11,9,2,2),STAB(11,9,2),ZO(11,9,2),ENG10800
     9DIV(11,9,2,2),STDEF(11,9,2,2),VORT(11,9,2,2),AVORT(11,9,2,2),ENGIENG10810
     *,SPD(2),CRS(2),SMU(2),SMV(2),QS(11,9,2,2),QSINIT,QFINL,QSFINL,    ENG10820
     1RH(11,9,2,2),Q(11,9,2,2),VOFINL,DFINL,VCINT,DINIT,DIFF,QINIT,     ENG10830
     2T(11,9,2,2),TD(11,9,2,2),E(11,9,2,2),ES(11,9,2,2),Z(11,9,2,12)    ENG10840
     3,STABI,STABF,PVORTI,PVORTF,POTDIF,QCIF                            ENG10841
C****                                                                   ENG10850
C     EVALUATE ENERGY INTEGRAL FOR KINEMATIC TRAJECTORY                 ENG10860
C****                                                                   ENG10870
C****                                                                   ENG10880
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C      COEFFICIENT FOR OPTIMUM FIRST GUESS.                                    ENG10890
C****                                                                          ENG10900
       ALPHA = .6                                                              ENG10910
C                                                                              ENG10920
       NCOUNT = 0                                                              ENG10930
       L=12                                                                    ENG10940
       AKINIT = .001*AKINIT                                                    ENG10950
       FINALK = .001*FINALK                                                    ENG10960
       EPSM = AMINIT - FINALM - (FINALK - AKINIT) + DELTAM                     ENG10970
C****                                                                          ENG10980
C      COMPUTE FROM EPSM THE DISTANCE TO CORRECT TRAJECTORY                    ENG10990
C           FOLLOWING DELTA QUANTITIES ARE IN METERS                           ENG11010
C****                                                                          ENG11020
   24  DELTAN =(-EPSM/(F(J)*SQRT(U1(L)**2+ V1(L)**2))*10**8)*ALPHA             ENG11030
C****                                                                          ENG11040
C      DELTAX IS IN THE SAME DIRECTION AS DELLAM AS GIVEN HERE                 ENG11050
C****                                                                          ENG11060
       DELTAX = DELTAN*V1(L)/SQRT(U1(L)**2 + V1(L)**2)                         ENG11070
       DELTAY =  DELTAN*U1(L)/SQRT(U1(L)**2 + V1(L)**2)                        ENG11080
C****                                                                          ENG11090
C      COMPUTE DISPLACEMENT IN DEGREES LATITUDE AND LONGITUDE                  ENG11100
C****                                                                          ENG11110
       DELLAM=(DELTAX/(6.371*10**6*COS(ALAT(L)/57.2958)))*57.2958              ENG11120
       DELPHI=(DELTAY/(6.371*10**6))*57.2958                                   ENG11130
C                                                                              ENG11140
       WRITE(6,501)                                                            ENG11150
  501  FORMAT(2X,'EPSM        FINAL M      INITIAL M      DELTAM',//)          ENG11160
       WRITE(6,502) EPSM,FINALM,AMINIT,DELTAM                                  ENG11170
  502  FORMAT(1X,F7.2,6X,F7.2,6X,F7.2,6X,F7.2,//)                              ENG11180
       WRITE(6,503)                                                            ENG11190
  503  FORMAT(2X,'DELTAN    DELTAX     DELTAY     DELLAM    DELPHI',//)       ENG11200
       WRITE(6,504) DELTAN,DELTAX,DELTAY,DELLAM,DELPHI                         ENG11210
  504  FORMAT(2X,3F9.0,2F8.2,//)                                               ENG11220
       IF(ABS(EPSM) .LT. .05) GO TO 78                                         ENG11230
       IF(FINALK .LT. .0045) GO TO 78                                          ENG11240
C                                                                              ENG11250
       XSUM=0.0                                                                ENG11260
       YSUM=0.0                                                                ENG11270
C****                                                                          ENG11280
C      SSUM IS THE TOTAL DISPLACEMENT DETERMINED BY THE INTERPOLATED WINDENG11290
C      FIELD FROM THE ENERGY ITERATION AT THE NEW POINTS.                      ENG11300
C****                                                                          ENG11310
       SSUM = 0.0                                                              ENG11320
C****                                                                          ENG11330
C      BEGIN LOOP TO ADJUST TRAJECTORIES FROM ABOVE ENERGY EQUATION            ENG11340
C      RESULTS.                                                                ENG11350
C****                                                                          ENG11360
       DO 80 L=1,NLDAY                                                         ENG11370
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      AL=L                                                                  ENG11380
      ALAT(L) = ALAT(L) + (AL/12.)*DELPHI                                   ENG11390
      ALONG(L) = ALONG(L)  + (AL/12.)*DELLAM                                ENG11400
C****                                                                       ENG11410
C     ROUTINE TO CONVERT LATITUDES AND LONGITUDES BACK INTO I,J FIELD.      ENG11420
C     ZJ AND ZI ARE RELATIVE GRID POINT DISTANCES FROM THE ORIGIN, IZ       ENG11430
C     AND JZ ARE THE COORDINATES OF THE LOWER LEFT HAND CORNER OF THE       ENG11440
C     BOX SURROUNDING THE PARCEL, XDIST AND YDIST ARE DEFINED AS BEFORE.    ENG11450
C****                                                                       ENG11460
      ZJ = (ALAT(L) - SOULAT + DELLAT)/DELLAT                               ENG11470
      ZI = (WELONG - ALONG(L) + DELONG)/DELONG                              ENG11480
      ANI = NI                                                              ENG11490
      ANJ = NJ                                                              ENG11500
      JZ = ZJ                                                               ENG11510
      AJZ = JZ                                                              ENG11520
      YDIST = (ZJ - AJZ)*DY                                                 ENG11530
C                                                                           ENG11540
      IZ = ZI                                                               ENG11550
      AIZ = IZ                                                              ENG11560
      XDIST = (ZI - AIZ)*DX(JZ)                                             ENG11570
C                                                                           ENG11580
      IF(AIZ .LT. 1.) GO TO 76                                              ENG11590
      IF(AIZ .GT. ANI) GO TO 76                                             ENG11600
      IF(AJZ .GT. ANJ) GO TO 76                                             ENG11610
      IF(AJZ .LT. 1.) GO TO 76                                              ENG11620
      GO TO 555                                                             ENG11630
   76 WRITE(6,77) IZ,JZ,L                                                   ENG11640
   77 FORMAT(2X,'TRAJECTORY TERMINATES AT IZ = ',I3,' JZ = ',I3,' AND       ENG11650
     1AT L = ',I3,//)                                                       ENG11660
      GO TO 78                                                              ENG11670
  555 CONTINUE                                                              ENG11680
C****                                                                       ENG11690
C     COMPUTATION OF WIND SPEEDS AT NEW TRAJECTORY POINTS                   ENG11700
C****                                                                       ENG11710
      U1(L)=U(IZ,JZ,K,L) + (U(IZ+1,JZ,K,L) - U(IZ,JZ,K,L))*(XDIST/DX(JZ)ENG11720
     1) + ((U(IZ,JZ+1,K,L) - U(IZ,JZ,K,L))*(DX(JZ)-XDIST)/(DY*DX(JZ)) +  ENG11730
     2 (U(IZ+1,JZ+1,K,L) - U(IZ+1,JZ,K,L))*(XDIST/(DY*DX(JZ))))*YDIST     ENG11740
C                                                                           ENG11750
      V1(L) = V(IZ,JZ,K,L) + (V(IZ+1,JZ,K,L) - V(IZ,JZ,K,L))*(XDIST/DX(JENG11760
     1Z))+ ((V(IZ,JZ+1,K,L) - V(IZ,JZ,K,L))*(DX(JZ)-XDIST)/(DY*DX(JZ))+  ENG11770
     2 (V(IZ+1,JZ+1,K,L) - V(IZ+1,JZ,K,L))*(XDIST/(DY*DX(JZ))))*YDIST     ENG11780
C                                                                           ENG11790
      XINC = 450.*U1(L)                                                     ENG11800
      YINC = 450.*V1(L)                                                     ENG11810
      XSUM=XSUM+XINC                                                        ENG11820
      YSUM = YSUM + YINC                                                    ENG11830
      SSUM = SSUM + SQRT(XINC**2 + YINC**2)                                 ENG11840
C                                                                           ENG11850
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   80 CONTINUE                                                                  ENG11860
C****                                                                           ENG11870
C      ROUTINE TO MAKE DISTANCE CORRECTION                                      ENG11880
C      SMEAS IS THE STREAMLINE DISPLACEMENT DETERMINED FROM THE                 ENG11890
C      COORDINATES OF THE ENERGY EQUATION ITERATED TRAJECTORY.                  ENG11900
C****                                                                           ENG11910
       L=1                                                                      ENG11920
       SMEAS = 0.0                                                              ENG11930
       DSTRAJ = SQRT((6371000.*(ALAT(L)-ALAT0)/57.2958)**2 +                    ENG11940
      1 (6371000.*COS(ALAT(L)/57.2958)*(ALONG(L)-ALONG0)/57.2958)**2)           ENG11950
C                                                                               ENG11960
       DO 809 L=2,NLDAY                                                         ENG11970
       SMEAS = SMEAS + DSTRAJ                                                   ENG11980
  809 DSTRAJ = SQRT((6371000.*(ALAT(L)-ALAT(L-1))/57.2958)**2 +                 ENG11990
     1(6371000.*COS(ALAT(L)/57.2958)*(ALONG(L)-ALONG(L-1))/57.2958)**2)         ENG12000
       SMEAS = SMEAS + DSTRAJ                                                   ENG12010
C****                                                                           ENG12020
C      COMPUTE DIFFERENCE BETWEEN DISPLACEMENT AT THE NEW ITERATION             ENG12030
C      COMPUTED FROM THE WIND FIELD AND FROM THE GEOMETRICALLY DETERMINED       ENG12040
C      POINTS.                                                                  ENG12050
C****                                                                           ENG12060
       DELS = (SSUM - SMEAS)*ALPHA                                              ENG12070
       L=12                                                                     ENG12080
C****                                                                           ENG12090
C      SIGN HAS BEEN CHANGED TO MINUS IN DELLAM EXPRESSION FOR A CHECK.         ENG12100
C****                                                                           ENG12110
       DELLAM=(57.2958*DELS*U1(L)/SQRT(U1(L)**2 + V1(L)**2))/(6371000.*         ENG12120
      1 COS(ALAT(L)/57.2958))      *(-1.)                                       ENG12130
       DELPHI=(57.2958*DELS*V1(L)/SQRT(U1(L)**2+V1(L)**2))/6371000.             ENG12140
C                                                                               ENG12150
       WRITE(6,806)                                                             ENG12160
  806 FORMAT(2X,'     DELS     SSUM     SMEAS     DELLAM     DELPHI')          ENG12170
       WRITE(6,807) DELS,SSUM,SMEAS,DELLAM,DELPHI                               ENG12180
  807 FORMAT(2X,3F10.0,2F6.2)                                                   ENG12190
C                                                                               ENG12200
       SDMDT1 = 0.0                                                             ENG12210
       DO 81 L=1,NLDAY                                                          ENG12220
       AL=L                                                                     ENG12230
       ALAT(L)=ALAT(L) + (AL/12.)*DELPHI                                        ENG12240
       ALONG(L) = ALONG(L) + (AL/12.)*DELLAM                                    ENG12250
C****                                                                           ENG12260
C      TERM IS MINUS IN ALONG EXPRESSION BECAUSE LONG INCREASES WITH            ENG12270
C      DECREASING I VALUES.                                                     ENG12280
C                                                                               ENG12290
C      ROUTINE TO CONVERT LAT + LONG BACK TO I,J FIELD                          ENG12300
C****                                                                           ENG12310
       ZJ=(ALAT(L) - SOULAT + DELLAT)/DELLAT                                    ENG12320
       JZ=ZJ                                                                    ENG12330
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      YDIST = (ZJ - JZ)*DY                                                    ENG12340
C                                                                             ENG12350
      ZI = (WELONG - ALONG(L) + DELONG)/DELONG                                ENG12360
      IZ=ZI                                                                   ENG12370
      XDIST = (ZI - IZ)*DX(JZ)                                                ENG12380
C                                                                             ENG12390
      IF (IZ .LT. 1)  GO TO 76                                                ENG12400
      IF (IZ .GT. NNI) GO TO 76                                               ENG12410
      IF (JZ .LT. 1) GO TO 76                                                 ENG12420
      IF(JZ .GT. NNJ) GO TO 76                                                ENG12430
C                                                                             ENG12440
      U1(L)=U(IZ,JZ,K,L) + (U(IZ+1,JZ,K,L) - U(IZ,JZ,K,L))*(XDIST/DX(JZ)ENG12450
     1) + ((U(IZ,JZ+1,K,L) - U(IZ,JZ,K,L))*(DX(JZ)-XDIST)/(DY*DX(JZ)) + ENG12460
     2 (U(IZ+1,JZ+1,K,L) - U(IZ+1,JZ,K,L))*(XDIST/(DY*DX(JZ))))*YDIST    ENG12470
C                                                                             ENG12480
      V1(L) = V(IZ,JZ,K,L) + (V(IZ+1,JZ,K,L) - V(IZ,JZ,K,L))*(XDIST/DX(JENG12490
     1Z))+ ((V(IZ,JZ+1,K,L) - V(IZ,JZ,K,L))*(DX(JZ)-XDIST)/(DY*DX(JZ))+ ENG12500
     2 (V(IZ+1,JZ+1,K,L) - V(IZ+1,JZ,K,L))*(XDIST/(DY*DX(JZ))))*YDIST    ENG12510
C                                                                             ENG12520
      DMDT(L) = DMDT1(IZ,JZ,K) + (DMDT1(IZ+1,JZ,K)-DMDT1(IZ,JZ,K))*(XDISENG12530
     1T/DX(JZ))  +  ((DMDT1(IZ,JZ+1,K) - DMDT1(IZ,JZ,K))*(DX(JZ) -       ENG12540
     2XDIST)/(DY*DX(JZ)) + (DMDT1(IZ+1,JZ+1,K) - DMDT1(IZ+1,JZ,K))*(XDISENG12550
     3T/(DY*DX(JZ))))*YDIST                                                   ENG12560
C                                                                             ENG12570
      SDMDT1 = SDMDT1 + DMDT(L)                                               ENG12580
C                                                                             ENG12590
   81 CONTINUE                                                                ENG12600
C                                                                             ENG12610
      L=NLDAY                                                                 ENG12620
      NCOUNT = NCOUNT + 1                                                     ENG12630
      DELTAM = SDMDT1/12.                                                     ENG12640
C****                                                                         ENG12650
C     ITERATION TO ADJUST TRAJECTORY IS NOW COMPLETE FOR STREAM FUNCTIONENG12660
C     AND FOR DISTANCE. CHECK ENERGY INTEGRAL FOR CONVERGENCE.                ENG12670
C****                                                                         ENG12680
      FINALM = PSIM(IZ,JZ,K,2) + (PSIM(IZ+1,JZ,K,2)   -                      ENG12690
     1  PSIM(IZ,JZ,K,2))*(XDIST/DX(JZ)) + ((PSIM(IZ,JZ+1,K,2) -              ENG12700
     2 PSIM(IZ,JZ,K,2))*(DX(JZ)-XDIST)/(DY*DX(JZ))+(PSIM(IZ+1,JZ+1,K,2) ENG12710
     3 - PSIM(IZ+1,JZ,K,2))*(XDIST/(DY*DX(JZ))))*YDIST                        ENG12720
C                                                                             ENG12730
      FINALK = .0005*(U1(L)**2 + V1(L)**2)                                    ENG12740
C                                                                             ENG12750
      EPSM = AMINIT - FINALM - (FINALK - AKINIT) + DELTAM                     ENG12760
C                                                                             ENG12770
      WRITE(6,8880)   EPSM,AMINIT,FINALM,FINALK,AKINIT,DELTAM                 ENG12780
 8880 FORMAT(//,' *DIAGNOSTIC*  ',6F12.2,//)                                  ENG12790
C                                                                             ENG12800
      IF(ABS(EPSM) .LT. .05) GO TO 88                                         ENG12810
```

```
      IF(NCCUNT .GT. 9) GO TO 88                                        ENG12820
      GO TO 24                                                          ENG12830
C                                                                       ENG12840
   88 CONTINUE                                                          ENG12850
C                                                                       ENG12860
      VFINAL = SQRT(U1(L)**2 + V1(L)**2)                                ENG12870
      ACCEL = (VFINAL - VINIT)*2./3.                                    ENG12880
C                                                                       ENG12890
      PFINAL = P(IZ,JZ,K,2) + (P(IZ+1,JZ,K,2) -                         ENG12900
     1 P(IZ,JZ,K,2))*(XDIST/DX(JZ)) + ((P(IZ,JZ+1,K,2) -                ENG12910
     2 P(IZ,JZ,K,2))*(DX(JZ)-XDIST)/(DY*DX(JZ)) +(P(IZ+1,JZ+1,K,2)      ENG12920
     3 - P(IZ+1,JZ,K,2))*(XDIST/(DY*DX(JZ))))*YDIST                     ENG12930
      OMEGA = (PFINAL - PINIT)* 2./3.                                   ENG12940
C                                                                       ENG12941
      STABF = STAB(IZ,JZ,2) + (STAB(IZ+1,JZ,2) - STAB(IZ,JZ,2))*(XDIST  ENG12942
     1/DX(JZ)) + ((STAB(IZ,JZ+1,2) - STAB(IZ,JZ,2))*(DX(JZ)-XDIST)/     ENG12943
     2(DY*DX(JZ)) + (STAB(IZ+1,JZ+1,2) - STAB(IZ+1,JZ,2))*(XDIST/(DY*   ENG12944
     3DX(JZ))))*YDIST                                                   ENG12945
C                                                                       ENG12950
      QFINL = Q(IZ,JZ,K,2) + (Q(IZ+1,JZ,K,2) - Q(IZ,JZ,K,2))*(XDIST/DX  ENG12960
     1(JZ)) + ((Q(IZ,JZ+1,K,2) - Q(IZ,JZ,K,2))*(DX(JZ)-XDIST)/(DY*DX(JZ)ENG12970
     2) + (Q(IZ+1,JZ+1,K,2) - Q(IZ+1,JZ,K,2))*(XDIST/(DY*DX(JZ))))*YDISTENG12980
C                                                                       ENG12990
      QSFINL = QS(IZ,JZ,K,2) + (QS(IZ+1,JZ,K,2) - QS(IZ,JZ,K,2))*(XDIST ENG13000
     1/DX(JZ)) + ((QS(IZ,JZ+1,K,2) - QS(IZ,JZ,K,2))*(DX(JZ)-XDIST)/(DY* ENG13010
     2DX(JZ)) + (QS(IZ+1,JZ+1,K,2) - QS(IZ+1,JZ,K,2))*(XDIST/(DY*DX(JZ) ENG13020
     3)))*YDIST                                                         ENG13030
C                                                                       ENG13040
      VOFINL = AVORT(IZ,JZ,K,2) + (AVORT(IZ+1,JZ,K,2) - AVORT(IZ,JZ,K,2)ENG13050
     1)*(XDIST/DX(JZ)) + ((AVORT(IZ,JZ+1,K,2) - AVORT(IZ,JZ,K,2))*(DX(JZENG13060
     2)- XDIST)/(DY*DX(JZ)) + (AVORT(IZ+1,JZ+1,K,2) - AVORT(IZ+1,JZ,K,2)ENG13070
     3)*(XDIST/(DY*DX(JZ))))*YDIST                                      ENG13080
C                                                                       ENG13090
      DFINL = DIV(IZ,JZ,K,2) + (DIV(IZ+1,JZ,K,2) - DIV(IZ,JZ,K,2))*     ENG13100
     1(XDIST/DX(JZ)) + ((DIV(IZ,JZ+1,K,2) - DIV(IZ,JZ,K,2))*(DX(JZ)-   ENG13110
     2XDIST)/(DY*DX(JZ)) + (DIV(IZ+1,JZ+1,K,2) - DIV(IZ+1,JZ,K,2))*    ENG13120
     3(XDIST/(DY*DX(JZ))))*YDIST                                        ENG13130
C                                                                       ENG13131
      PVORTF = STABF*VOFINL*1000.0                                      ENG13132
C                                                                       ENG13140
      TIMSAT = ((PSAT-PINIT)/(PFINAL-PINIT))*1.5                        ENG13150
C                                                                       ENG13160
      ENGFL = FINALM + 1111.48*QFINL + FINALK/1000.                     ENG13170
C                                                                       ENG13180
      DIVDIF = DFINL - DINIT                                            ENG13190
      VORDIF = VOFINL - VOINT                                           ENG13200
      ENGDIF = ENGFL - ENGIT                                            ENG13210
      QDIF = QFINL - QINIT                                              ENG13211
```

```
      POTDIF = PVCRTF - PVORTI                                          ENG13212
C                                                                       ENG13220
C****                                                                   ENG13230
C     PRINTOUT OF FINAL TRAJECTORIES                                    ENG13240
C****                                                                   ENG13250
      WRITE(6,1000)                                                     ENG13260
 1000 FORMAT(1H1)                                                       ENG13270
      WRITE(6,70) NCOUNT                                                ENG13280
   70 FORMAT(2X,' NUMBER OF ITERATIONS REQUIRED = ',I3,/)               ENG13290
      WRITE(6,71) ALATO,ALONGO                                          ENG13300
   71 FORMAT(2X,'FINAL ENERGY ITERATED TRAJECTORIES AT 7.5 MINS INTERVALENG13310
     1S BEGINNING AT LATITUDE = ',F5.2,' AND AT LONGITUDE =',F6.2,/)    ENG13320
      WRITE(6,72)                                                       ENG13330
   72 FORMAT(3X,'TIME STEP',5X,'LATITUDE',5X,'LONGITUDE',6X,'U',11X,'V')ENG13340
      WRITE(6,73)ALATO,ALONGO,UO(I,J,K),VO(I,J,K)                       ENG13350
   73 FORMAT(9X,'0',7X,F5.2,7X,F6.2,6X,F6.1,6X,F6.1,/)                  ENG13360
      DO 74 L=1,NLDAY                                                   ENG13370
   74 WRITE(6,75)L,ALAT(L),ALONG(L),U1(L),V1(L)                         ENG13380
   75 FORMAT(8X,I2,7X,F5.2,7X,F6.2,6X,F6.1,6X,F6.1,/)                   ENG13390
C                                                                       ENG13400
      WRITE(6,82) PINIT,PFINAL,OMEGA,ACCEL                              ENG13410
   82 FORMAT(//,2X,'INITIAL P =',F5.1,',FINAL P =',F5.1,',OMEGA(MB/HR)  ENG13420
     1=',F5.1,', ACCELERATION(M/SEC-HR) =',F5.1,//)                     ENG13430
C                                                                       ENG13440
      WRITE(6,91) QINIT,QFINL,QDIF,QSINIT,QSFINL                        ENG13450
   91 FORMAT(//,2X,' INITIAL Q(GM/GM)= ',F9.4,' FINAL Q= ',F9.4,' CHANGEENG13460
     1= ',F9.4,' INITIAL QS= ',F9.4,' FINAL QS= ',F9.4,//)              ENG13470
C                                                                       ENG13480
      WRITE(6,92) VCINT,VOFINL,VORDIF                                   ENG13490
   92 FORMAT(//,2X,'INITIAL VORTICITY(10**-4)= ',F9.3,' FINAL VORTICITY ENG13500
     1(10**-4)= ',F9.3,2X,'CHANGE=',F9.3,//)                            ENG13510
C                                                                       ENG13520
      WRITE(6,93) DINIT,DFINL,DIVDIF                                    ENG13530
   93 FORMAT(//,2X,'INITIAL DIVERGENCE(10**-4)= ',F9.3,'FINAL DIVERGENCEENG13540
     1(10**-4)= ',F9.3,2X,'CHANGE=',F9.3,//)                            ENG13550
C                                                                       ENG13560
      WRITE(6,94) AMINIT,FINALM                                         ENG13570
   94 FORMAT(//,2X,'INITIAL MONT. STR. FUNC. =',F9.3,' FINAL MONT. STR. ENG13580
     1FUNC. =',F9.3,//)                                                 ENG13590
C                                                                       ENG13600
      WRITE(6,95) AKINIT,FINALK                                         ENG13610
   95 FORMAT(//,2X,'INITIAL KINETIC ENERGY =',F9.3,' FINAL KINETIC ENERGENG13620
     1Y =',F9.3,//)                                                     ENG13630
C                                                                       ENG13640
      WRITE(6,97) PSAT,TIMSAT                                           ENG13650
   97 FORMAT(//,2X,'SATURATED PRESSURE = ',F8.2,2X,'TIME OF SATURATION  ENG13660
     1= ',F7.3,//)                                                      ENG13670
C                                                                       ENG13680
```

```
      WRITE(6,98) ENGIT,ENGFL,ENGDIF                                    ENG13690
   98 FORMAT(//,2X,'INITIAL ENERGY(10**7 ERG/GM) =',F9.3,2X,'FINAL ENERGENG13700
     1Y =',F9.3,2X,'CHANGE =',F9.3,//)                                  ENG13710
C                                                                       ENG13720
      WRITE(6,66) STABI,STABF                                           ENG13721
   66 FORMAT(//,2X,'INITIAL STABILITY= ',F9.3,' FINAL STABILITY= ',     ENG13722
     1F9.3,//)                                                          ENG13723
C                                                                       ENG13724
      WRITE(6,89) PVORTI,PVORTF,POTDIF                                  ENG13725
   89 FORMAT(//,2X,'INITIAL POT. VORT.(10**-10 DEG. K SEC CM/GM)= ',    ENG13726
     1F9.3,' FINAL POT. VORT.= ', F9.3,' CHANGE= ',F9.3,//)             ENG13727
C****                                                                   ENG13728
C     THIS SUBRCUTINE RETURNS TO THE END CF TRAJ, NCT MAIN              ENG13730
C****                                                                   ENG13740
   78 CONTINUE                                                          ENG13750
      RETURN                                                            ENG13760
      END                                                               ENG13770
```

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13. ABSTRACT

One and one-half hour isentropic trajectories obtained from an objective computer technique for the 308K, 312K, 320K and 332K isentropic surfaces are investigated for the May 28, 1967, severe local storm case in the National Severe Storm Laboratory (NSSL) network. In conjunction with the trajectories, air parcel properties of vertical motion, acceleration, divergence, vorticity, static stability and total energy have been studied with respect to development, growth, movement and decay of the storm system. Basic assumptions are that the flow is frictionless and adiabatic over the entire grid. The results show that the observed winds do provide some skill in formulating isentropic trajectories which demonstrate the presence of storm activity in the specific region. The investigation of a mesoscale inertial-gravity wave having a wave length of 150 KM, period of 3 hours and phase speed of 14 m sec^{-1} is also presented, with its possible correlation to the onset of the severe storm.

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